OPTIONS méditerranéennes

Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas

Edited by: A. López-Francos, M. Jouven, C. Porqueddu, H. Ben Salem, A. Keli, A. Araba, M. Chentouf

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Centre International de Hautes Etudes Agronomiques Méditerranéennes

International Centre for Advanced Mediterranean Agronomic Studies

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Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas

Editors: A. López-Francos, M. Jouven, C. Porqueddu, H. Ben Salem, A. Keli, A. Araba, M. Chentouf

Proceedings of the 1st Joint Meeting of the FAO-CIHEAM Network for Research and Development in Sheep and Goats (Subnetworks on Nutrition and Production Systems) and the FAO-CIHEAM Subnetwork on Mediterranean Forage Resources, jointly organised by the École Nationale d'Agriculture de Meknès (ENA), under the aegis of the Moroccan Ministry of Agriculture, Fisheries, Rural Development, Water and Forests (MAPMDREF), and by the Mediterranean Agronomic Institute of Zaragoza/International Centre of Advanced Mediterranean Agronomic Studies (CIHEAM-Zaragoza); with the collaboration of the Food and Agriculture Organization of the United Nations (FAO) and the H2020 Project iSAGE (Innovation for Sustainable Sheep and Goat Production in Europe, GA no. 679302).

Meknes (Morocco), 23 to 25 October 2019

CIHEAM ZARAGOZA

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Foreword

The 1st Joint Meeting of the FAO-CIHEAM Network for Research and Development in Sheep and Goats (Subnetworks on Nutrition and Production Systems) and the FAO-CIHEAM Subnetwork for Research and Development of Mediterranean Forage Resources was held at Morocco's National School of Agriculture in Meknes, from 23 to 25 October 2019. The event was of particular significance, for three reasons. First, it coincided with the 50th anniversary of the Mediterranean Agronomic Institute of Zaragoza (CIHEAM Zaragoza). Second, it was the first joint meeting of these FAO-CIHEAM Networks. Third, it addressed a major challenge for the Mediterranean region: the efficiency and resilience of feed resources and small ruminant production in the light of global challenges.

Small ruminant breeding plays an important role in the agricultural livelihood systems in different Mediterranean countries. However, farmers and shepherds find difficulties to earn a decent living or have a satisfactory lifestyle, due to many reasons: low product prices and high input prices, low productivity and capitalisation, harsh working conditions, decreased attractiveness of farming, social disregard, lack of services in rural areas, competition for land or conflicts of land use with other activities that are considered more profitable, etc. The pillars of sustainability, productivity, profitability and environmental and social benefits of this sector are mainly linked to grazing resources that unfortunately undergo continuous and often severe degradation due to the changes to which they are submitted. In some cases, they are subject to abusive and often excessive use and conversely, in other cases they are almost abandoned. The effects of climate change are already being felt: reduction in rainfall, rise in temperatures, and successive years of drought or with extreme climatic events, etc. This situation has led to a mutation of extensive grazing systems to farming systems based on feed supplementation. A sustainable management of small ruminant farms requires a better knowledge of the "soil-plant-animal" interactions and integrated approaches, taking into account the socio-economic system. Especially, the resilience of small ruminant systems requires an efficient management of natural and cultivated forage resources in order to face climatic and social challenges.

The objective of the Meeting was to encourage the participation of and interaction between scientists, technicians and professionals to exchange their experiences and to update knowledge on the promising options that would improve small ruminant productivity and enhance the conservation of pastoral forage resources in the Mediterranean countries. This Meeting was organised by the National School of Agriculture of Meknes (ENA) under the aegis of Morocco's Ministry of Agriculture, Maritime Fisheries, Rural Development, Water and Forests (MAPMDREF), and by the Mediterranean Agronomic Institute of Zaragoza – International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM Zaragoza), with the collaboration of the Food and Agriculture Organization of the United Nations (FAO) and the H2020 Project iSAGE (Innovation for Sustainable Sheep and Goat Production in Europe, Grant Agreement n679302).

This Joint Meeting gathered 136 participants from 15 different countries and lasted for three days, including a day's field visit organised with the collaboration of the Moroccan "Association Nationale Ovine et Caprine (ANOC)". The scientific and technical presentations were structured in different plenary and parallel sessions providing a framework for scientific and technical exchanges, with invited lectures and oral or poster contributions. The plenary sessions were devoted to questions of common interest for the two Networks: What production systems and product chains to meet the societal demand; how to meet the challenge of climate change in Mediterranean agro-pastoral systems; and how to improve the contribution of grazed and cropped forages in feeding systems. The parallel sessions provided time to present and discuss specific issues of interest of the Sheep and Goat Nutrition Subnetwork (Nutritional strategies to improve adaptation and production effi-

ciency) and of the Mediterranean Forage Resources Subnetwork (Promising forage resources for Mediterranean production systems). Finally, a workshop presenting the main results and recommendations from the 4-year EU research project iSAGE (Innovation for Sustainable Sheep and Goat production in Europe) was included in the programme. This workshop was the continuation of a project's international training course held during the two previous days at the ENA Meknès.

This issue of *Options Méditerranéennes* gathers the full articles of most of the presentations (keynotes, orals and posters) of the Meeting. We thank the panel of article reviewers for their support to this publication: A. Araba, S. Ates, M. Bengoumi, A. Bernués, I. Casasús, M. Chentouf, P. de Frutos, A. de Vega, P. Gaspar, S. Giger-Reverdin, I. Hadigeorgiou, A. Kyriazopoulos, L. Lopez Marco, G. Luciano, D. Martin Collado, Y. Mena, E. Molina, G. Moreno, M. Mounsif, M. Napoleone, F. Pacheco, P.A. Swanepoel, D. Yáñez and A. Zoghlami.

We acknowledge the FAO Office for North Africa, the iSAGE project, the members of the Scientific and Organising Committees, and the staff and students of ENA Meknès for their valuable contributions to the organisation of this Meeting.

Abdelhafid Keli (ENA Meknes, Morocco. Local convener)

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Antonio López-Francos (CIHEAM Zaragoza, Spain. Coordinator (interim) of the FAO-CIHEAM Subnetwork on Sheep and Goat Production Systems)

Préface

La première réunion conjointe du Réseau FAO-CIHEAM de Recherche et Développement sur les Ovins et les Caprins (Sous-Réseaux Nutrition et Systèmes de Production) et du Sous-Réseau FAO-CIHEAM de Recherche et Développement sur les Ressources Fourragères Méditerranéennes a eu lieu à l'École Nationale d'Agriculture de Meknès, au Maroc, du 23 au 25 octobre 2019. Les raisons conférant à cet évènement une signification particulière étaient au nombre de trois. En premier lieu, il coïncidait avec le 50ème anniversaire de l'Institut Agronomique Méditerranéen de Zaragoza (CIHEAM-Zaragoza). Ensuite, il s'agissait de la première réunion conjointe de ces Réseaux FAO-CIHEAM. Finalement, la réunion abordait un enjeu majeur pour la région méditerranéenne : l'efficience et la résilience des ressources fourragères et de la production de petits ruminants à la lumière des défis globaux.

L'amélioration génétique des petits ruminants joue un rôle important pour permettre que les systèmes agricoles pourvoient aux moyens d'existence des producteurs dans les différents pays méditerranéens. Il s'avère cependant difficile pour les agriculteurs et éleveurs de gagner décemment leur vie ou d'avoir un mode d'existence satisfaisant, pour plusieurs raisons : bas prix des produits et prix élevé des intrants, productivité et capitalisation faibles, dures conditions de travail, moindre attractivité de l'agriculture, faible valorisation sociale, insuffisance des services en milieu rural, concurrence foncière ou conflits pour l'utilisation des terres face à d'autres activités considérées plus profitables, etc. Les piliers de la durabilité, productivité, rentabilité et bénéfices environnementaux et sociaux de ce secteur, sont principalement liés aux pâturages et ressources herbagères qui malheureusement subissent une dégradation continue et souvent sévère comme conséquence des mutations auxquelles ils sont soumis. Dans certains cas, ils font l'objet d'une exploitation abusive voire excessive tandis qu'ailleurs ils sont à l'inverse pratiquement abandonnés. Les effets du changement climatique se font déjà sentir : réduction de la pluviométrie, augmentation des températures, et années successives de sécheresse ou d'événements climatiques extrêmes, etc. Cette situation a entraîné une mutation où les systèmes de pâturage extensifs se sont tournés vers des systèmes basés sur la supplémentation des animaux. Pour une gestion durable des élevages de petits ruminants, il sera nécessaire d'avoir une meilleure connaissance des interactions sol-plante-animal et de mettre en place des approches intégrées tenant compte du système socio-économique. En particulier, la résilience des systèmes de petits ruminants nécessite une gestion efficiente des ressources fourragères naturelles et cultivées afin de faire face aux défis climatiques et sociaux.

L'objectif de la Réunion était d'encourager la participation et l'interaction entre scientifiques, techniciens et professionnels pour leur permettre d'échanger leurs expériences et d'actualiser leurs connaissances sur des options prometteuses visant à augmenter la productivité des petits ruminants et à améliorer la conservation des ressources fourragères des pâturages dans les pays méditerranéens. La Réunion était organisée par l'École Nationale d'Agriculture de Meknès (ENA) sous l'égide du Ministère de l'Agriculture, de la Pêche Maritime, du Développement Rural et des Eaux et Forêts du Maroc, et par l'Institut Agronomique Méditerranéen de Zaragoza – Centre International de Hautes Études Agronomiques Méditerranéennes (CIHEAM-Zaragoza), avec la collaboration de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) et du Projet H2020 iSAGE (Innovation for Sustainable Sheep and Goat Production in Europe, Accord de subvention nº 679302).

Cette Réunion conjointe a rassemblé 136 participants de 15 pays différents pour une durée de trois journées, comprenant une sortie de terrain d'une journée organisée avec la collaboration de l'Association Nationale Ovine et Caprine (ANOC) du Maroc. Les présentations scientifiques et techniques étaient structurées en différentes sessions plénières ou parallèles qui fournissaient un ca-

dre pour le débat scientifique et technique, les contributions étant sous forme de présentations principales, présentations orales et posters. Les sessions plénières ont porté sur des questions d'intérêt commun pour les deux réseaux : Quels systèmes de production et chaînes de produits pour répondre aux demandes sociétales ? Répondre au défi posé par le changement climatique dans les systèmes agropastoraux méditerranéens, et Améliorer la contribution du fourrage pâturé ou récolté dans les systèmes alimentaires. Les sessions parallèles ont pris le temps de présenter et de débattre sur des enjeux spécifiques d'intérêt pour le Sous-Réseau sur la Nutrition des Ovins et Caprins (stratégies nutritionnelles pour améliorer l'adaptation et l'efficience productive des ovins et caprins) et du Sous-Réseau sur les Ressources Fourragères Méditerranéennes (ressources fourragères prometteuses pour les systèmes de production de la région méditerranéenne). Finalement, un atelier présentant les principaux résultats et recommandations des 4 années de recherche du projet de l'UE iSAGE (Innovation for Sustainable Sheep and Goat production in Europe) a été inclus au programme ; cet atelier était la continuation d'un cours international de formation lié au projet et qui avait eu lieu à l'ENA Meknès pendant les deux journées précédentes.

Ce numéro d'*Options Méditerranéennes* rassemble le texte intégral des articles concernant la plupart des contributions (présentations principales, présentations orales et posters) de la Réunion. Nous tenons à remercier, pour leur appui à cette publication, l'ensemble des personnes ayant révisé les articles : A. Araba, S. Ates, M. Bengoumi, A. Bernués, I. Casasús, M. Chentouf, P. de Frutos, A. de Vega, P. Gaspar, S. Giger-Reverdin, I. Hadigeorgiou, A. Kyriazopoulos, L. López Marco, G. Luciano, D. Martin Collado, Y. Mena, E. Molina, G. Moreno, M. Mounsif, M. Napoleone, F. Pacheco, P.A. Swanepoel, D. Yáñez et A. Zoghlami.

Nos remerciements vont également au Bureau sous-régional de la FAO pour l'Afrique du Nord, au projet iSAGE, aux membres du Comité scientifique et du Comité d'organisation, et au personnel et aux étudiants de l'ENA Meknès pour leur précieuse contribution à l'organisation de cette Réunion.

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1st Joint Meeting of the FAO-CIHEAM Network for Research and Development in Sheep and Goats (Subnetworks on Nutrition and Production Systems) and the FAO-CIHEAM Subnetwork on Mediterranean Forage Resources

Meknes (Morocco), 23 to 25 October 2019

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Session 1

What production systems and product chains to meet the societal demand?

Resilient and efficient small ruminant value chains in the Mediterranean basin: challenges and opportunities from society and consumers' needs

R. Zanoli[1]

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Mediterranean areas are characterized by a high proportion of sheep and goats in the total ruminant livestock units (30% vs 10% worldwide); such proportion is slowly decreasing, while it increases at a global level. A possible explanation is that small ruminant farming is mainly associated with traditional systems, which performance and resilience are limited in the present context.

An interesting concept, introduced by Nassim Nicholas Taleb, is the notion of "anti-fragility", which goes beyond resilience or robustness: an anti-fragile system does not only survive to the shocks it endures, it gets better after them. An anti-fragile sheep and goat value chain would: (i) focus on the right knowledge, which enables to detect, understand and endure the changes affecting the supply chain; (ii) adjust in real-time, in order to seize the chances of positive change; (iii) be based on a network approach, which is less fragile than a linear pipeline. A common fallacy of sheep and goat research in this respect is the low importance and priority which have been given, until recently, to innovation (in products, processes, marketing). Innovation could help answering strategic issues for Mediterranean areas: the remuneration of ecosystem services, a better compliance with agro-ecological principles, an improved access to the market for pastoral products.

The change in the consumer landscape represents a major challenge for traditional sheep and goat value chains. In the Mediterranean basin, the population is concentrated near the coast while small ruminants are found mainly in the inner lands. The population is ageing and the time devoted to cooking meals has been reduced by half in the last 30-40 years. Lamb and goat meat is tasty and benefits from a natural, genuine, authentic image; though, it is usually rich in fat, requires a long cooking time and its strong taste has become unfamiliar to the younger generations. As a consequence, consumers increasingly prefer chicken or veggie meat. However, consumers are not all alike and market segmentation could help commercialise small ruminant meat. Collective brands, fancy packaging (small portions, with labels and illustrations) or ready-to-use (seasoned or cooked) products are promising strategies to increase sales for the small ruminant meat sector. In a reputation economy based on social media, advertising the products with the help of renowned chefs could help to make sheep and goat meat more trendy.

This presentation focussed on meat, because at the present moment it is the most fragile component of sheep and goat value chains. Many PDOs exist for dairy products (cheese) and goat milk is highly demanded in Europe; still, logistic issues and a better organization of dairy supply chains should be addressed, especially in Southern Mediterranean countries. Because specialized systems are more fragile, a general issue in the future should be to encourage diversified systems, possibly based on dual-purpose breeds. And of course, organising supply chains and new, innovative, distribution channels.

1. This summary was elaborated by Magali Jouven (AgroSup Montpellier, France) on the basis of the presentation delivered by Raffaele Zanoli in the 1st Joint Meeting of the FAO-CIHEAM Networks on Sheep and Goats and on Mediterranean Pastures, "Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas" (Meknes, Morocco, 23 to 25 October 2019).

Impact of feed quality on animal health and food safety

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Abstract. The livestock sector accounts for 40% of the global value of agricultural production and enhances the livelihoods and food security of nearly 1.3 billion people in the world. Animal feed accounts for about 79% of global vegetable protein consumption (including fodder) and 58% of protein concentrates (FAOStat, 2017). Animal feed is an important source of hazards to the human food chain, its safety must be assessed prior to its feeding to animals. Feed safety includes the impact on human as well as animal health and welfare, which, in turn, can affect productivity. Safety assessments are often multifaceted. The range of potential hazards associated with feed is broad and possibly increasing with the rising importance of different feed sources and feed production technologies. The main chemical hazards are persistent organic pollutants, veterinary drug residues, organochlorine and other pesticides, potentially toxic elements, mycotoxins, plant toxins, etc. Biological hazards are mainly bacterial, viral, parasitic, fungal pathogens and prions. While physical hazards include nanomaterials and radionuclides. Feed safety assessment is costly and needs highly qualified laboratories. Therefore, risk assessment, risk management and risk communication are key elements for ensuring feed safety. FAO, WHO and OIE have developed international standards for feed safety and established the ad hoc Codex Intergovernmental Task Force on Animal Feeding. FAO and WHO provide the scientific basis to Codex through the Joint FAO/WHO Expert Committee on Food Additives (JECFA); the Joint FAO/WHO Meetings on Pesticide Residues (JMPR), the Joint Expert Meetings on Microbiological Risk Assessment (JEMRA) and the Joint FAO/WHO ad hoc Expert Meetings on Safety Assessment of Food Derived from Biotechnology. FAO has developed a series of programmes to support member countries in ensuring feed safety including compilation and dissemination of information, promotion of wide alliances and partnership with the private sector, technical assistance and capacity– and institutional building; and awareness raising and policy advice.

Keywords. Animal feeds – Safety – Hazards – Risk – Assessment – Management – Comunication – International Standars – Codex.

Impact de la qualité des aliments pour animaux sur la santé animale et la sécurité sanitaire des produits alimentaires

Résumé*. Le secteur de l'élevage représente 40% de la valeur globale de la production agricole et améliore les moyens d'existence et la sécurité alimentaire de près de 1,3 milliard d'habitants. L'alimentation animale représente environ 79% de la consommation mondiale de protéines végétales (fourrages compris) et 58% des protéines de concentrés (FAOStat, 2017). Les aliments pour animaux sont une importante source de dangers pour la chaîne alimentaire humaine, et leur sécurité sanitaire doit être évaluée avant de les distribuer aux animaux. La sécurité sanitaire des aliments pour animaux inclut l'impact sur la santé et le bien-être des être humains ainsi que des animaux, ce qui peut avoir des conséquences pour la productivité. Les évaluations de sécurité sanitaire portent souvent sur de multiples facettes. L'éventail de dangers potentiels liés aux aliments pour animaux est vaste et pourrait augmenter avec l'importance grandissante de différentes sources et technologies de production d'aliments pour animaux. Les principaux dangers chimiques sont les polluants organiques persistants, les résidus de médicaments vétérinaires, les organochlorés et autres pesticides, les éléments potentiellement toxiques, les mycotoxines, les toxines de plantes, etc. Les dangers biologiques sont principalement les organismes bactériens, viraux, parasitaires, pathogènes fongiques et prions, tandis que parmi les dangers physiques figurent les nanomatériaux et radionucléides. L'évaluation de la sécurité sanitaire des aliments pour animaux est coûteuse et nécessite des laboratoires très qualifiés. Donc, l'évaluation, la gestion et la communication des risques sont des éléments-clés pour assurer la sécurité sanitaire des aliments pour animaux.*

La FAO, l'OMS et l'OIE ont développé des normes internationales pour la sécurité sanitaire des aliments pour animaux et ont instauré le Groupe spécial intergouvernemental du Codex pour l'alimentation animale. La FAO et l'OMS fournissent au Codex les bases scientifiques à travers le Comité mixte FAO/OMS d'experts sur les additifs alimentaires (JECFA), le Comité mixte FAO/OMS d'experts sur les résidus de pesticides (JMPR), le Comité mixte d'experts FAO/OMS sur l'évaluation des risques microbiologiques (JEMRA) et le Comité mixte d'experts FAO/OMS sur l'évaluation des risques des aliments obtenus au moyen des biotechnologies. La FAO a développé une série de programmes pour appuyer les pays membres afin d'assurer la sécurité sanitaire des aliments pour animaux, y compris la compilation et la diffusion de l'information, la promotion de larges alliances et partenariats avec le secteur privé, l'assistance technique et le renforcement des compétences et des institutions, et la sensibilisation ainsi que le conseil politique.

Mots-clés. *Aliments pour animaux – Sécurité sanitaire – Dangers – Risque – Evaluation – Gestion – Communication – Normes internationales – Codex.*

Diversité des systèmes de production agricole dans le massif forestier du Boutaleb, Algérie

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Résumé. Le massif forestier du Boutaleb, situé au Nord-Est algérien, constitue un atout environnemental et socio-économique pour la région. La présente étude, réalisée en 2008 dans le cadre d'un projet d'aménagement, a pour objectif d'analyser l'agriculture et l'élevage dans le massif. 116 exploitations d'élevage ont été approchées à travers l'étude du ménage, des structures de production, du fonctionnement de l'unité et de son rapport à la forêt. Les statistiques descriptives ont permis de décrire globalement l'agriculture et l'élevage, alors que l'analyse des correspondances multiples et la classification ascendante hiérarchique ont permis de créer une typologie des systèmes de production. L'étude a montré que 97 % des exploitations sont à caractère familial, la SAU est de 4 ha, et les éleveurs possédant des terres agricoles, réservent en moyenne 96 % à la céréaliculture pour la consommation humaine et surtout animale. D'autre part, le pâturage des ressources sylvo-pastorales est primordial et intervient pendant une durée moyenne de six mois par an. L'étude de la typologie a permis de distinguer 3 systèmes d'exploitation qui diffèrent selon leurs environnements par leurs objectifs, moyens et stratégies : (1) Petite exploitation pastorale, (2) Exploitation agro-pastorale (3) Grande exploitation diversifiée. A la lumière de ces résultats, des propositions ont été faites afin de protéger les ressources sylvo-pastorales et promouvoir la synergie entre l'agriculture et l'élevage d'un côté et la forêt de l'autre.

Mots clés. Algérie – Forêt semi-aride – Systèmes d'élevage – Sylvo-pastoralisme – Projet d'aménagement.

Diversity of agricultural production systems in the Boutaleb forest, Algeria

Abstract. *The Boutaleb forest, located in northeastern Algeria, is an environmental and socio-economic asset for the region. This study, conducted in 2008 as part of a development project, aims to analyze agriculture and livestock production in the region. 116 livestock farms were approached through the study of the household, the production structures, the farm functioning and its relation to the forest. Descriptive statistics were used to describe agriculture and stockbreeding, while the multiple correspondence analysis and hierarchical ascending classification were performed to create a typology of production systems. The study showed that 97% of farms are family-type, the average UAA is 4 ha, and Farmers who own agricultural land, reserve 96% of the area for cereals for family consumption and especially for animals. On the other hand, grazing of sylvo-pastoral resources is essential and takes place for an average of six months per year. The study of the typology allowed distinguishing between 3 production systems which differ according to their environments by their objective, means and strategies: (1) Small pastoral farm, (2) Agro-pastoral farm (3) Large and diversified farm. In the light of these results, proposals have been made to protect sylvo-pastoral resources and promote synergy between agriculture, stockbreeding and the forest.*

Keywords. *Algeria – Semi-arid forest – Livestock systems – Sylvo-pastoralism – Development project.*

I – Introduction

Le massif forestier du Boutaleb, situé au Nord-Est algérien et faisant partie des chaines de Hodna, constitue un atout pour la région du point de vue environnemental (protection des sols, biodiversité), mais aussi socio-économique en permettant à des communautés humaines de s'installer et de se maintenir grâce à son environnement et ses ressources favorables à la mise en place d'activités vitales telles que l'agriculture et l'élevage.

Dans un contexte de développement local des massifs forestiers à l'échelle nationale, et vue son importance, le massif a bénéficié en 2008 d'un projet d'aménagement. Le présent travail s'inscrit justement dans ce contexte et vise à comprendre les systèmes d'exploitation agricole au sein des exploitations d'élevage à travers les dimensions socio-économiques, agricoles et l'analyse de la relation entre l'élevage et la forêt. L'objectif est d'identifier et de décrire la diversité des exploitations d'élevage afin de proposer les actions adéquates pour leur développement tout en garantissant la préservation du patrimoine forestier.

II – Matériel et méthodes

1. Région d'étude

D'une superficie de 28 416 ha, le massif du Boutaleb constitue un maillon important de la partie orientale de la chaine du Hodna ; il est situé entre les hautes plaines sétifiennes et le bassin du Hodna (Bertraneu, 1952). Son point culminant s'élève à 1890 m d'altitude. La région reçoit des précipitations variables selon l'année et selon l'exposition, elles varient de 550 à 600 mm/an sur le versant Nord et peuvent atteindre 754 mm en altitude, alors qu'elles n'atteignent que 312 mm/an sur le versant Sud. Les températures extrêmes du mois le plus froid et du mois le plus chaud enregistrent des moyennes de –2.3°C et +32°C (Boudy, 1955).

2. Démarche méthodologique

A. Approche

Un système de production est «un ensemble structuré de moyens de production combinés entre eux pour assurer une production végétale et/ou animale en vue de satisfaire les objectifs et besoins de l'exploitant et de sa famille» (Jouve, 1992).

B. Enquêtes

Après une étape de pré-enquête auprès de différents organismes technico-administratifs (mairies, direction et subdivisions des services agricoles) pour identifier les caractéristiques générales de l'agriculture et de l'élevage dans le massif, 116 exploitations d'élevage choisies au hasard et réparties sur le massif ont été enquêtées. L'enquête met l'accent sur trois volets : le ménage, les structures et le fonctionnement de l'unité de production (cultures, élevage et relation avec la forêt). Elle est réalisée en un seul passage et dure entre 30 et 60 minutes.

C. Analyse statistique

A l'aide du logiciel statistique SPAD (v 5.0), nous avons effectué l'analyse descriptive visant à synthétiser les caractéristiques générales des exploitations. Ensuite, une typologie des systèmes de production a été effectuée en utilisant l'analyse des correspondances multiples (ACM) suivie de la classification ascendante hiérarchique (CAH). Les variables retenues sont relatives aux caractéristiques de l'exploitation en terme socio-économique (Composition du ménage et revenu), structurel (surfaces agricoles, équipement et composition du troupeau) et fonctionnel (cultures et leur destination, utilisation des ressources sylvo-pastorales et stratégie de commercialisation des animaux).

III – Résultats et discussion

1. Caractéristiques générales de l'agriculture au Boutaleb

Notre étude a montré que 97% des exploitations du massif du Boutaleb ont un caractère familial (ne font pas appel à la main d'œuvre salariée). La SAU moyenne est de 4 ha et seuls 11 % des exploitations sont dotées d'équipement agricole, qui est un signe de dépendance envers l'extérieur. La production végétale est dominée par la céréaliculture pluviale destinée à l'alimentation humaine (blé) et animale (orge), et en cas de présence d'eau d'irrigation, la céréaliculture en irrigué (avoine, orge en vert), le maraichage et le tabac font leur apparition.

L'élevage est en général sylvo-pastoral extensif représenté essentiellement par les petits ruminants de races locales. Cet élevage est détenu par une majorité de petits éleveurs naisseurs, peu organisés et peu encadrés. L'élevage ovin, ancré dans les traditions de la population nord-africaine (Rondia 2006), est présent dans la quasi-totalité de l'échantillon (99%) et souvent associé au caprin (60 % des cas). L'élevage bovin est présent dans 35 % des exploitations avec des effectifs faibles (1 à 3 vaches) et situé le plus souvent au versant nord du massif grâce à des conditions microclimatiques plus favorables. Il est orienté vers la production laitière pour la famille, alors que le veau est destiné à l'engraissement et permet la rentabilisation de l'élevage. Les bovins sont alimentés à base de produits issus de l'agriculture de l'exploitation, mais aussi provenant de l'extérieur (concentrés composés, son du blé).

2. Systèmes de production identifiés

Notre étude des exploitations d'élevage au Boutaleb a permis de distinguer 3 systèmes différents allant du plus extensifs au plus soutenu :

A. Exploitation sylvo-pastorale

Ce type représentant 9 % du total et concerne les exploitations pratiquant l'élevage pastoral comme unique activité. L'exploitation est conduite par des bergers habitant l'intérieur et le sud du massif et ne disposant pas de terre cultivables, de matériel agricole, ou de main d'œuvre externe. Il s'agit des élevages extensifs de troupeaux de petits ruminants et parfois de caprins seuls ne dépassant pas les 35 têtes. L'exploitation des ressources sylvo-pastorale durant plus de 7 mois/an est vitale pour le maintien de l'exploitation puisque les revenus externes dans ces unités de production sont absents ou très faibles (<150 €/mois). La complémentation se fait uniquement par la paille achetée pour assurer la survie des animaux, et la commercialisation des animaux se fait en maigre dès qu'il y a un besoin de financement. La variabilité de l'offre pastorale selon les années est la principale cause du maintien ou de la disparition de l'exploitation. Ce système nécessite le soutien des services forestiers et agricoles pour lutter contre les fluctuations interannuelles de l'offre pastorale à travers une meilleure gestion de l'espace et un meilleur suivi technique (alimentation, reproduction, hygiène).

B. Exploitation agro-sylvo-pastorale

Représentant 64 % du total, celles-ci sont situées en lisière sud et ouest pour la majorité. Les surfaces agricoles en possession sont inférieures à la moyenne (<4ha), du coup les chefs d'exploitations recourent à la location pour la culture du blé et de l'orge. Ces unités ne disposent pas de matériel agricole et louent également des entrepreneurs pour travailler leurs terres. L'élevage est orienté vers les troupeaux mixtes de taille moyenne (35 à 70 têtes), et valorise les produits de la ferme disponibles en quantités suffisantes mais aussi les ressources sylvo-pastorales pendant une durée moyenne de 6 mois durant les périodes de repousse de la végétation ou de manque de ressources agricoles (chaumes). Les animaux commercialisés ont un bon état d'embonpoint parce qu'ils bé-

néficient soit de complémentation durant des périodes assez longues, soit de périodes d'engraissement. Le niveau de vulnérabilité de ce type d'exploitations est sensiblement moins élevé. L'accès à la terre, l'eau et l'équipement sont les éléments clés pour le développement de ces exploitations.

C. Grandes exploitations diversifiées

Représentant 27 % du total. Concerne des exploitations dont l'unité familiale est grande et complexe (plusieurs familles et/ou plusieurs générations). Elles sont situées notamment au nord du massif, disposant de terres agricoles supérieures à la moyenne (> 4 ha) en propriété et en partie louées et possédant un équipement agricole. Ces exploitations mobilisent de l'eau pour la culture du tabac, du maraîchage, et des céréales que l'élevage valorise par la suite à travers leurs produits (orge) et/ou coproduits (paille). La culture des fourrages est souvent pratiquée et représente une différenciation importante par rapport aux deux autres types. L'élevage concerne de grands troupeaux ovins principalement (> 70 têtes). La présence du bovin est également à noter alors que l'élevage caprin est marginal. Les ressources sylvo-pastorales entrent dans l'alimentation des ovins durant une période plus courte (4 mois) comparativement aux deux autres types. Les revenus tirés des céréales, des cultures de rentes (tabac), ou provenant de l'extérieur (>300 €/mois) participent à renforcer le système de production après en avoir assuré la sécurisation et la structuration de l'exploitation. Les éleveurs de ce groupe, à la recherche de la performance et possédant les atouts nécessaires, sont de potentiels collaborateurs pour un éventuel programme d'amélioration génétique.

IV – Conclusion

Notre étude a permis de mesurer l'importance de la diversité de l'agriculture et l'élevage au Boutaleb, qui joue un rôle dans le maintien de l'équilibre et la valorisation de cet espace. Elle constitue également un atout pour le développement local puisqu'elle engendre une variété de produits dont l'identification et la valorisation à travers la création de labels de qualité ou de nouvelles activités (éco-tourisme par exemple) permettrait l'amélioration des revenus de la population et ainsi renforcer les systèmes de production et d'apaiser la pression sur la forêt.

Elle a permis aussi d'identifier les exploitations les plus vulnérables dont il faudrait renforcer les capacités agricoles et pastorales par la mise en place de points d'eau collectifs pour l'irrigation et le développement des plantations pastorales par exemple. De plus, l'intégration du pastoralisme dans les pratiques sylvicoles permet une meilleure gestion sylvicole en assurant à la fois une économie pour les forestiers et des ressources alimentaires pour les animaux.

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A collaborative multi-stakeholder analysis of the sheep and goats sector challenges in Europe

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Abstract. This study aimed to identify the challenges of the sheep and goat sector in Europe as part of the iSAGE project. A total of 90 stakeholders were surveyed in 2018 following a participatory approach and each challenge was analysed in terms of i) relevance; ii) easiness to address and iii) stakeholders needed to take action. Differences in the relevance and easiness to address the challenges were compared between products (dairy vs meat), species (sheep vs goats), production system (intensive vs semi-intensive vs extensive), geographical region (Southern vs Central-Europe) and type of stakeholder (private vs public sector). A priority for action index was calculated to identify the key challenges, which combined high relevance and easiness to address. The high heterogeneity in the small ruminant sector across Europe was reflected in the variability observed in the perception of the challenges that this sector is facing. The main differences were found between regions (Southern vs Central Europe). The type of product and farming system explained moderate differences between challenges whereas species explained little differences. Overall, the top 10 challenges for prioritization included 5 internal weaknesses (Low promotion of local breeds; Poor business management training; Low professionalization; Slow adoption of innovations; Low adaptability of high producing breeds) and 5 external threats (Low consumer education; Low consumer knowledge on farming; Researchers not addressing real problems; Unfair trade/lack of traceability; Poor recognition of farming public services). Internal weaknesses need more action from the sector itself (farmers and associations), while external threats require action from governments in collaboration with the sector.

Keywords. Challenges – Multi-stakeholder – Small ruminants.

Une analyse multipartite collaborative des défis du secteur ovin et caprin en Europe

***Résumé**. Cette étude visait à identifier les défis du secteur ovin et caprin en Europe dans le cadre du projet iSAGE. Au total, 90 parties prenantes ont été interrogées selon une approche participative et chaque défi a été analysé en termes de i) pertinence; ii) la facilité à traiter et iii) les parties prenantes doivent prendre des mesures. Les différences de pertinence et de facilité à relever les défis ont été comparées entre les produits (produits laitiers et viandes), les espèces (ovins et caprins), le système de production (intensif ou semi-intensif ou extensif), la région géographique (Europe méridionale et centrale) et le type partie prenante (secteur privé vs public). Un indice de priorité d'action a été conçu pour identifier les principaux défis, qui allient haute pertinence et facilité de résolution. La grande hétérogénéité du secteur des petits ruminants en Europe s'est reflétée dans la variabilité observée dans la perception des défis auxquels ce secteur est confronté. Les principales différences ont été observées entre les régions (Europe du Sud et Europe centrale). Le type de produit et le système d'exploitation expliquent des différences modérées entre les défis, tandis que les espèces expliquent peu de différences. Globalement, les 10 principaux défis en matière de hiérarchisation comprenaient 5 faiblesses internes (faible promotion des races locales; faible formation en gestion des affaires; faible professionnalisation; adoption lente des innovations; faible adaptabilité des races à haute production) et 5 menaces externes (faible éducation des consommateurs; faible consommation des consommateurs). connaissances sur l'agriculture; chercheurs ne s'attaquant pas à de vrais problèmes; commerce injuste / manque de traçabilité; mauvaise reconnaissance des services publics). Les faiblesses internes nécessitent davantage d'action de la part du secteur lui-même (agriculteurs et associations), tandis que les menaces extérieures nécessitent une action des gouvernements en collaboration avec le secteur.*

***Mots-clés.** Défis – Multi-acteur – Petits ruminants.*

I – Introduction

The EU sheep and goat sector has been experiencing economic and structural difficulties in recent decades. These difficulties have caused a consistent decrease in livestock numbers following outbreaks of contagious diseases and policy changes in public funding schemes. Many farmers are currently becoming discouraged and leaving the sector because of a combination of socio-economic reasons. Moreover, as sheep and goat farming is among the less remunerative agricultural activities, it does not encourage investments or new entrants from younger generations of farmers.

The project H2020 iSAGE (Innovation for Sustainable Sheep and Goats in Europe) envisages contributing to make the European Sheep and Goat sectors more sustainable, competitive and resilient. Part of the project activities is to identify and quantify the importance of the current and future challenges that may compromise the sustainability of sheep and goat industry in Europe. To identify and quantify these challenges, iSAGE uses a participative multi-stakeholder approach with industry and research institutions working together.

This multi-stakeholder approach is required when dealing with complex and multi-side systems as the European sheep and goat sector to understand how to create change, implement research, and facilitate new ways of thinking (O'Brien *et al*., 2013). Integration and perceptions of knowledge affect how problems are identified and framed, the capacity for generation of innovative and practical solutions, the relevance of outcomes to policy and the extent of participation in learning (Bracken and Oughton, 2013). Traditional assumptions of researchers as the sole producers of knowledge are increasingly being replaced by activities that include multi-way interaction and co-production of knowledge between researchers, decision-makers and other beneficiaries of science (Francis and Goodman, 2010).

The objective of the study was to identify and quantify the main challenges that the sheep and goat sector faces in Europe, the perception of the relevance of such challenges throughout the different sector stakeholders; the difficulties to address such challenges and the different stakeholders that need to take action to address these challenges.

II – Materials and methods

iSAGE multi-stakeholder network included farmers, farmer associations, researchers and industry organisations that work directly with farmers or farmer groups (www.isage.eu). The researchers and industry organisations in iSAGE have diverse roles and represent the sheep and goat industries in a variety of ways. All these stakeholders took part in the participatory process described in detail below. The multi-stakeholder approach aims to provide the analysis with a comprehensive and wide view of the sector challenges that goes beyond unidirectional views of individual stakeholders. This multi-stakeholder approach has been recently described in detail by Belanche *et al*., (2020) but in summary the identification and quantification of the challenges to the EU sheep and goat sectors followed several stages:

i) Stage 1 involved collation of information from work packages 1 and 2 within iSAGE, literature review of existing EU reports, specific description of the sheep and goat production sector in each participating country (Greece, France, Spain, UK, Italy, Finland and Turkey) and semi-structured interviews with farmers. The main challenges identified in this exercise were categorised as 'technical / social', 'environmental', 'market' and 'policy / financial'. Moreovoer, all challenges were classified into two categories depending on if they were considered farm internal weaknesses or external threats.

ii) Workshop 1: A first workshop was held in Bilbao, Spain, (24th May 2018) to discuss the first list of challenges and to collect suggestions for other challenges to be included. The workshop was done with 3 small groups of around 15 people each and produced additional issues to be considered in following stages.

iii) Developing and conducting the Survey: a survey was developed using the challenges identified from the outcomes of the reports from each country, the semi-structured interviews with farmers and the first workshop. Thirty challenges in total were selected based on previous analysis and the outcome of the discussions distributed in the same four areas described above (Table 1). From the 30 identified challenges, we developed questions to ensure consistency in interpretations of questions and data collection. The types of knowledge exchange and evaluations were diverse so questions were kept mostly simple to help understand and score.

Table 1. List of challenges included in the assessment survey

Farm internal weaknesses	Farm external threats
Sector level	**Society level**
– Sector fragmentation/Lack of integration	– Low consumer education in local products
– Low cooperation between farmers	– Farmer role unrecognised by society
– No attractive to young farmers	– Low social knowledge about farming
– Low female involvement	– Poor recognition of farming public services
Farm level	– Low consumer demand
– Slow adoption of innovations	**Market level**
– Poor business management training	– Market monopolised
– Lack of professionalization	– Unfair trade / Lack of traceability
Farming systems level	– Uncertainty of meat and milk prices
– Low promotion of local breeds	– Volatility of commodity prices
– Low adaptability of high productive breeds	**Production factor level**
– Low integration livestock and agriculture	– Limited access to land
Overarching level	– Difficult access to capital
– Animal health issues	**Environmental level**
– High subsidy dependency	– Wildlife conflicts
– Low competitiveness	– Climate change threats
	Policy level
	– Uncertainty in future changes in subsidies
	– EU policy without scientific evidence
	– Environmental policy against intensification
	Science level
	– Researchers not address real problems

Three questions were then developed for each challenge:

1) Assess the perception of the relevance using the following scale: 1=Very low, 2=Low, 3=Medium, 4=High and 5=Very high
2) Evaluate the easiness of addressing each challenge using the following scale: 1=Very difficult, 2=Difficult, 3=Medium, 4=Easy and 5=Very Easy; and
3) Identify the main stakeholders (from a provided list including i) Government, ii) Farmers, iii) Associations of producers, iv) Academia, v) Processing industry, vi) Consumers and vii) Retailers) that should take action to address the each challenge.

III – Results and discussion

Six out of 30 challenges were relevant or very relevant (average scores ≥ 4) (in order of relevance): 1) Uncertain meat & milk prices, 2) Volatile commodity prices, 3) Low farm income / difficulty to access to capital, 4) low youth involvement, 5) high subsidy dependency and 6) uncertainty in future

changes in subsidies. All (but low youth involvement) refer to external threats, which are out of the control, or are extremely difficult to be managed by farmers (and or farmer institutions), reflecting a perception of the sector of having a weak position to deal with the most important challenges that it faces. This highlights the need to involve different stakeholders (especially governmental institutions) in the strategic solutions to propose.

The perception of the relevance of internal weaknesses differed between dairy vs meat production systems and south vs central European countries, while external threats were mainly perceived differently among systems (Table 2). Participants from dairy systems perceived internal weaknesses associated to the sector and farm level more relevant than those from meat production systems. Likewise, internal weaknesses were considered more relevant in south vs central European countries as well in extensive as compared to more intensive production systems. The goat sector, in comparison to the sheep sector, was perceived as having higher internal weaknesses derived from the farm structure, whereas the sheep sector was perceived as having higher external threats associated to the society. The farm intensification level had not effect on the relevance of internal weaknesses but it showed a decreasing relevance of the external threats as the level of intensification increased. Both sectors (public and private) had a similar view about the relevance of internal weaknesses and external threats as no differences were noted across sectors.

Table 2. Effect of the type of product, species, production system, geographical location and farming sector on the relevance of internal and external challenges in challenges

	Product			Species			System[1]				Region			Sector		
Relevance	Dairy	Meat	*P*[2]	Sheep	Goat	*P*[2]	Int.	Semi.	Ext.	*P*[2]	South	Central	*P*[2]	Public	Private	*P*[2]
Internal																
Overall	3.62	3.20	**	3.41	3.63	ns	3.40	3.63	3.42	ns	3.63	3.00	***	3.48	3.49	ns
Sector level	3.70	3.32	*	3.57	3.58	ns	3.45	3.77	3.49	ns	3.66	3.30	*	3.57	3.59	ns
Farm level	3.57	3.26	ns	3.37	3.69	*	3.48	3.59	3.36	ns	3.66	2.87	***	3.53	3.37	ns
Farming system	3.55	3.00	**	3.24	3.65	†	3.25	3.47	3.38	ns	3.58	2.71	***	3.32	3.46	ns
Overarching	3.51	3.53	ns	3.59	3.37	ns	3.20	3.61	3.66	ns	3.45	3.71	ns	3.67	3.25	ns
External																
Overall	3.70	3.58	ns	3.66	3.65	ns	3.47	3.65	3.81	*	3.63	3.76	ns	3.62	3.72	ns
Society	3.72	3.59	ns	3.73	3.56	*	3.46	3.74	3.77	†	3.61	3.88	†	3.63	3.75	ns
Market	3.96	3.87	ns	3.95	3.89	ns	4.00	3.81	3.99	ns	3.90	4.04	ns	3.86	4.07	†
Prod. factors	3.78	3.84	ns	3.70	4.00	†	3.46	3.65	4.19	**	3.80	3.81	ns	3.82	3.77	ns
Environmental	3.43	3.40	ns	3.43	3.38	ns	2.80	3.37	3.91	***	3.33	3.71	*	3.47	3.32	ns
Policy	3.64	3.25	*	3.53	3.51	ns	3.43	3.58	3.53	ns	3.54	3.45	ns	3.49	3.57	ns
Sciences	3.20	3.07	ns	3.03	3.40	ns	2.84	3.32	3.24	ns	3.25	2.86	ns	3.05	3.33	ns

[1]System: Int. (intensive); Semi. (Semiextensive); Ext. (extensive).

[2]Pvalue: ****P*<0.001; ***P*<0.01; **P*<0.05; † P<0.1.

The sheep and goat sector is very fragmented and the main characteristics vary for each Member State, or even for each production area: species (sheep, goat, combined), type of farming (milk, meat), systems (suckler or suckler-fattener / intensive or extensive), types of products (heavy lambs, light lambs), structures (small or large), importance of the activity within the area (from very important to marginal) (Ares, 2011). Our survey indicated that this fragmentation may be more of a threat for the dairy sector, probably in relation to the complexity of the market as compared to meat. Also, the highly fragmented production models in Mediterranean countries, in comparison to those in central Europe, may explain the difference in perception across geographical locations countries.

For the four categories of challenges considered in the survey (technical / social, market, environmental and policy), the perception between the different expert groups varied substantially. The overall relevance of the internal challenges and some external challenges (e.g. low social knowledge about farming, low consumer educaton in local products, lack of treaceability or climate chache threats) was higher for the dairy systems whereas the threat ´low consumer demand´ was higher for meat systems (Belanche *et al*., 2020). The consumption of lamb in Europe, particularly in northern Europe, is beset by a poor image and high prices. Sheep is perceived to be traditional

meat that is difficult to cook and has a taste that's not to everyone likes (Ares, 2011). In particular the consumption of lamb by young consumers is decreasing. Products such as leg of lamb or stewing lamb have no appeal to single people or young couples, as they are often family-sized portions and cuts that are complicated to prepare or need to be cooked for a long time. It is interesting to note that when new products are introduced to the market that are specially aimed at young consumers, such as ground lamb in the United Kingdom or mince lamb in Ireland, sales increase rapidly, which suggests low consumer demand can be addressed by offering new products.

The assessment of perception on how easy the different challenges are to be addressed showed that on average none were scored as 'easy' or 'very easy'. Out of the 30 challenges considered, 7 were perceived as 'difficult' or 'very difficult' (≤ 2) and these were (in order of difficulty): Volatile commodity prices, Uncertain meat & milk prices, Climate change, Low income / Limited access to capital, Market monopolised, Subsidy dependency and Fragmented sector. The degree of difficulty to address a challenge or threat seems to be more inherent to the challenge than the type of production system. As a result, the perception of the easiness to address the challenges was not substantially affected by the type of product and species whereas the production system, geographical region and sector seem to play a role in determining the difficulty to address those challenges.

The priority index (Table 3) was calculated to identify those challenges that had been scored as relevant and not very difficult to address, so strategies can be developed to prioritize efforts towards them. The index calculation ranged from 6.31 and 10.9. The 10 challenges that had the highest scores (above 8.70) were (in ranking order): Low consumer education about products, Low promotion of local breeds, Low social knowledge about farming, Poor business management training, Researchers not addressing real problems, Unfair trade, lack of traceability, Low professionalization, Slow adoption of innovations, Low adaptability of high producing breeds and Poor recognition of farming public services. Half of the top 10 challenges were internal weaknesses and the other half corresponded to external threats indicating that both farmers and external stakeholders (mainly government, associations of producers) should take further actions to address the current challenges of the small ruminal sector.

Table 3. Heatmap describing the priority indexes and the relevant actors required to address the main challenges and threats in the small ruminant sector for the sustainability

	Rank	Priority index	Nº actors	Government	Farmers	Producers associations	Academia	Processing industry	Consumers	Retailers
INTERNAL CHALLENGES										
Low promotion of local breeds	2	10.04^{mn}	2.5	27	27	23	22	0	1	0
Poor business management training	4	9.52^{klm}	3.0	29	25	25	12	5	2	2
Lack of professionalization	7	9.08^{jkl}	3.5	28	21	28	17	6	0	0
Slow adoption of innovations	8	8.86^{ijkl}	3.4	21	27	26	19	6	1	1
Low adaptability of high productive breeds	9	8.74^{hijk}	1.9	15	24	24	34	2	0	0
Low competitiveness	13	8.37^{fghij}	3.9	16	24	16	7	16	7	14
Low integration of livestock and agriculture	14	8.36^{fghij}	2.7	32	26	21	15	2	3	1
High subsidy dependency	15	8.24^{efghij}	2.8	43	20	20	4	3	8	1
Low cooperation between farmers	18	7.85^{cdefgh}	2.0	7	49	40	1	1	0	1
No attractive to young farmers	20	7.75^{cdef}	3.4	28	23	30	6	5	6	2
Low female involvement	24	7.44^{bcde}	1.9	31	29	28	7	1	3	0
Parasites and infectious diseases	25	7.18^{abcd}	2.2	15	33	22	29	0	1	0
Sector fragmentation / Lack of integration	26	7.01^{abc}	3.3	10	26	30	4	20	2	7
EXTERNAL CHALLENGES										
Low consumer education in local products	1	10.91^{n}	3.4	29	7	22	10	14	10	8
Low social knowledge about farming	3	9.74^{lm}	4.1	21	12	23	17	6	15	7
Researchers not address real problems	5	9.37^{klm}	2.8	20	19	20	33	5	2	2
Unfair trade / Lack of traceability	6	9.32^{klm}	3.6	23	12	17	4	19	10	15
Poor recognition of public services of farming	10	8.72^{hijk}	3.2	36	20	13	11	3	15	2
Uncertainty in future changes in subsidies	11	8.70^{ghijk}	2.6	48	18	14	10	3	6	1
Farmer role unrecognised by society	12	8.66^{ghijk}	4.7	19	19	18	11	9	16	8
EU policy without scientific evidence	16	8.16^{defghij}	1.6	50	2	16	31	0	1	0
Environmental policy against intensification	17	8.10^{defghi}	2.3	44	13	18	17	6	1	1
Uncertainty of meat and milk prices	19	7.78^{cdefg}	4.0	19	13	12	3	25	8	21
Low consumer demand	21	7.53^{bcdef}	3.9	7	9	11	8	21	22	22
Low farm income / Difficult access to capital	22	7.51^{bcdef}	3.3	33	16	15	7	13	6	10
Limited access to land	23	7.50^{bcdef}	2.2	55	21	19	5	0	0	0
Volatility of commodity prices	27	6.83^{ab}	3.5	28	13	9	1	27	8	14
Wildlife conflicts	28	6.80^{ab}	2.3	39	29	13	12	0	6	0
Market monopolised	29	6.76^{ab}	3.1	26	12	13	2	20	6	21
Climate change threats	30	6.28^{a}	3.2	28	20	15	25	9	2	2

IV – Conclusions

The high heterogeneity in the small ruminant production systems across Europe is reflected in the variability observed in the perception of relevance of the challenges and threats that face this sector. Based on the expert group's surveys it was observed that the geographical region (Southern vs Cental Europe) is one of the main drivers that determine the relevance and difficulties to address the main challenges of the small ruminant sector. The type of product (meat vs dairy) and level of intensification can also modulate the relevance of these challenges whereas the type of livestock species (sheep vs goats) is much less relevant.

The use of the priority index as an indicator of the relevance and easiness to address the small ruminant challenges identified the most immediate challenges to address.

It was clear that internal weaknesses need more action from the sector itself (farmers and associations), while external threats require a strong involvement of Governments. Moreover, it was noted that a combined action of government, farmers and associations of producers should take place to address these challenges.

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Factors influencing sheep farmer attitudes towards breeding tools across Mediterranean breeds

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Abstract. One of the key challenges for the success of sheep breeding programmes is to achieve a wide farmer engagement, which in many cases, especially in sheep breeds, is far from being fully reached. Understanding farmer attitudes and its driving factors give key insights for designing extension activities aiming to increase farmers' uptake of breeding tools. However, farmer attitudes towards breeding tools have only been studied in very few occasions. Here we investigated the attitude of Spanish and Greek sheep farmers towards breeding tools and the main factors affecting it. A farmer survey that includes a scale to measure farmers' attitudes was designed. The survey included additional information on farm and farmer profiles. Data were analysed using multivariate statistical methods. Two hundred fifteen farmers from Greece and Spain completed the survey. We found large heterogeneity in farmers´ attitudes not only across countries and breeds but also within them. Although there were farmers with a clear positive attitude towards genetic and genomic breeding (n=58) and farmers with a very positive attitude towards traditional selection (n=58), the majority had a balanced attitude towards genetic and genomic breeding and traditional phenotypic selection (n=82). In both counties, farmers of business-oriented intensive farms (contrary to family or family business farms) tended to have the highest positive attitude towards genetic and genomic breeding compared to traditional selection. This study indicates the need of tailoring extension programs to demonstrate farmers the usefulness of genetic and genomic breeding tools to improve animal performance.

Keywords. Sheep genetic & genomic – Breeding tools – Farmer attitudes – Mediterranean – Local breeds.

Facteurs influençant les attitudes des éleveurs ovins vers des outils de sélection dans les races méditerranéennes

Résumé. *L'un des défis principaux pour le succès des programmes d'amélioration ovine est de parvenir à un fort engagement des éleveurs, ce qui bien souvent, en particulier pour les races ovines, est loin d'être le cas. La compréhension des attitudes des éleveurs et de leurs facteurs déterminants nous donnent une perception fondamentale pour mettre au point des activités de vulgarisation visant à augmenter la maîtrise des outils d'amélioration par les éleveurs. Toutefois, les attitudes des éleveurs envers les outils d'amélioration n'ont été que rarement étudiées. Ici nous examinons l'attitude des éleveurs espagnols et grecs concernant les outils d'amélioration ainsi que les facteurs qui l'influencent. Une enquête sur les éleveurs a été conçue, incluant une échelle pour mesurer leurs attitudes. L'enquête comprenait une information additionnelle sur la ferme et les profils des éleveurs. Les données ont été analysées en utilisant des méthodes statistiques multivariées. Un total de 215 éleveurs grecs et espagnols ont rempli l'enquête. Nous avons trouvé une large hétérogénéité pour les attitudes des éleveurs, non seulement entre pays et races mais aussi entre eux. Bien que certains éleveurs avaient une attitude nettement positive concernant l'amélioration génétique et génomique (n=58) et certains autres très positive concernant la sélection traditionnelle (n=58), la majorité montraient une attitude mitigée envers l'amélioration génétique et génomique et la sélection phénotypique traditionnelle (n=82). Dans les deux pays, les éleveurs possédant des exploitations intensives de type entreprise (contrairement aux exploitations familiales ou exploitations de type entreprise mais familiales) tendaient à avoir l'attitude la plus positive concernant l'amé-*

lioration génétique et génomique en comparaison à la sélection traditionnelle. Cette étude indique le besoin de concevoir sur mesure les programnes de vulgarisation pour montrer aux éleveurs l'utilité des outils d'amélioration génétique et génomique afin d'augmenter les performances animales.

Mots-clés. *Génétique et génomique ovine – Outils d'amélioration – Attitudes des éleveurs – Méditerranée – races locales.*

I – Introduction

The success of breeding programmes relies on farmers' engagement. This may seem self-evident, however in many cases, especially in sheep local breeds raised under extensive systems, farmer use of breeding tools and participation in breeding programmes is usually far from optimum levels. As a result, the genetic gain achieved within breeds is limited. Nevertheless, research in the field of animal breeding has focused on the development of methods and techniques to evaluate the genetic potential of animals ignoring the effect of social factors on farmer breeding decision-making process. In recent years, farmers' views about genetic improvement, their trait preferences, and the link between these and implementation of breeding programmes are attracting the attention of academics. Understanding farmer attitudes and specifically the factors influencing them may give key insights for designing extension activities aiming to increase farmers' uptake of breeding tools and participation in existing programmes. However, to our knowledge, farmer attitudes towards breeding tools have scarcely been studied. The objective of our study was to explore the attitude of Greek and Spanish sheep farmers towards breeding tools and to identify its main drivers.

II – Methods

We designed a farmer survey that included a scale to measure farmers' attitudes towards breeding tools. The scale consisted of a set of attitudinal statements that allow for the determination of farmer attitudes. Farmer denoted their level of agreement with these statements using a 6-item Likert scale (Likert, 1932). The survey requested additional data on farm size, farming system characteristics, ownership structure, use of reproductive and breeding technologies, farmer age, education and family profile. The set of statements that form the attitudinal scale were developed and tested in a previous study implemented with more than 600 beef and sheep farmers of local and international breeds in Australia, New Zealand and Spain (Martin-Collado *et al.,* 2021). The latter study used standard methodologies for the development of attitudinal scales (e.g. Dunlap *et al*., 2000) and found two independent attitudinal dimensions; one related to farmer attitudes towards traditional selection and another one toward genetic and genomic breeding. In the present study, we used those two dimensions ("Att. toward traditional selection" and "Att. toward G&G breeding") to derive an attitudinal gradient variable ("Att. gradient Traditional–G&G") as the subtraction of the second to the first; therefore, the more positive the value of "Att. gradient Traditional–G&G" the more positive the attitude toward traditional selection compared to genetic/ genomic breeding, and vice versa. The relationship between the attitudinal statements included in the survey, the attitudinal dimensions and the attitudinal gradient are shown in Table 1. The survey was conducted in Greece and Spain between the end of 2019 and the beginning of 2019. A total of 215 farmers were surveyed; after quality check of data, 198 surveys were analysed; 86 in Greece and 112 in Spain covering seven (Assaf, n=7; Chios, 13; Crossbreed, 36; Frizarta, 3; Kefalonias, 1; Lacaune, 24; Lesvos, 2) and four (Assaf, 29; Churra, 11; Latxa, 32; Manchega, 40) breeds respectively. We grouped farmers according to "Att. gradient Traditional–G&G" using k-means cluster analysis. Then, linear discriminant analysis was used to explore how country, breed, farm and farmer profile relate to attitudes based on its power to help discriminating among farmer attitudinal groups. The discriminating power of the variables was evaluated by estimating probabilities of misclassification of farmers among attitudinal groups (Lachenbruch *et al*., 1979).

Table 1. Correlation between attitudinal statements, attitudinal dimensions and attitudinal gradient

Attitudinal statement	Att. toward traditional selection	Att. toward G &G breeding	Att. gradient Traditional G&G
Using breeding values to select rams/ewes improves the performance of sheep better and faster than other ways of selecting	-0.4	0.4	-0.4
The use of genomic and DNA/gene information to select rams/ewes will improve the performance of sheep better and faster than any other method	-0.2	0.8	-0.6
It is important that opportunities for selection of sheep with genomic and DNA/gene information are fully utilized	-0.2	0.8	-0.6
It is important that opportunities for selection of sheep with new genetic developments are fully utilized	-0.2	0.7	-0.6
The appearance of a ram/ewe is sufficient for telling its performance	0.8	-0.6	0.7
The appearance of progeny fully indicates how good the ram/ewe is	0.8	-0.1	0.6

III – Results

The distribution of farmer attitudes towards traditional selection and genetic/genomic breeding was very heterogeneous across and within breeds and countries (Fig. 1). The cluster analysis revealed three groups of farmers according to their attitude: (i) “Pro-Traditional selection” farmers (n=58; average “Att. gradient Traditional–G&G”=1.76), (ii) “Balance Traditional-Genetic and Genomic” farmers (82; -0.19), and (iii) “Pro-Genetic and Genomic breeding” farmers (58; -1.77).

We developed three discriminant models to distinguish among attitudinal groups (i) in both countries, (ii) in Greece, and (iii) in Spain. In addition, we also discriminate between “Pro-traditional selection” and “Pro-Genetic and Genomic breeding” farmers ignoring observations from the intermediate group.

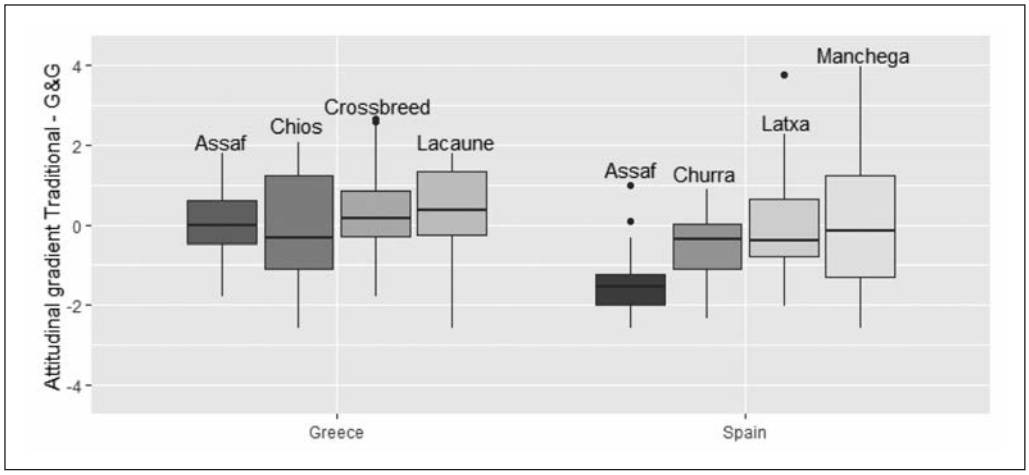

Fig. 1. Distribution of farmers’ attitudes towards traditional selection (positive values) versus genetic/genomic breeding (negative values) across breeds and countries.

We found that in the analysis considering both countries (all data), the minimum misclassification rate was 0.41. The latter indicates that 59% of farmers can be correctly assigned to their attitudinal group. Such rate was achieved considering Breed, Production system (intensive, vs extensive/semi-extensive) and Pedigree recording (whether farmers record pedigree or no) in the model. Discrimination between just "Pro-Traditional selection" and "Pro-Genetic and Genomic breeding" farmer groups was easier; there was a misclassification rate of 0.19 with a model including Breed, the Production system and the Farm property regime (business, family business or family farm). In Greece, farmer age influenced farmer attitudes; the best fitted model included Production system, Breed, Age, and Performance recording data to produce a misclassification rate of 0.37. In Spain education level was related to farmer attitude; the best model produced a misclassification rate of 0.36 including Production system, Breed, Education level and Performance recording data. Table 2 shows the value of the driving factors of farmer attitudes across farmer groups.

Table 2. Factors related to farmer attitudes towards breeding

Farming system and farmer factors		Attitudinal farmer group		
		Balance Pro-traditional selection	Traditional G&G	Pro-G&G
[1]Production system	Intensive	22.4	28	56.9
	Extensive/semi-extensive	77.6	72	43.1
[1]Farm property regime	Business	0.0	6.1	17.2
	Family business	34.5	41.5	50.0
	Family farming	65.5	52.4	32.8
Pedigree recording (% of farmers)		34.5	50.0	84.5
Performace data recording (% of farmers)		46.6	56.1	91.4
[1,2]Education level (Spain)	Basic	48.0	36.6	39.1
	Intermediate	12.0	17.1	8.7
	University	40.0	46.3	52.2
[2]Age (Greece)		44.2 ± 11.6	40.5 ± 9.7	40.2 ± 8.6

[1] Perc. of farmers of each attitudinal group that falls in each category of production system, property regime and education level.

[2] Education level is on related to farmer attitudes in Spain and age only in Greece.

IV – Discussion

The present study shows that sheep farmer attitudes towards breeding tools are very heterogeneous. Three farmer groups were identified and all of them were present in both countries and in all breeds; farmers that had a "pro-traditional selection" attitude, farmers that had a clear "pro-genetic and genomic breeding" attitude and farmers who had a similar attitude towards both breeding paradigms. The latter was the largest group representing those farmers who think both approaches help their selection decisions.

Overall, our results indicated farming system and business orientation, age and education level as the major factors influencing farmers' attitude towards genetic/genomic breeding tools. Farmers of intensive business-oriented systems had a more positive attitude towards genetic and genomic breeding. Farmers of this group usually collect information that is formally analysed and translated into genetic and economic tools. On the other hand, farmers with an attitude pro-traditional selection tend to record neither pedigree nor performance data, maybe reflecting that their decision making is generally based on opinions not backed by formal data analysis. It should be noted however, that under extensive farming conditions controlled mating and artificial insemination are challenging making genetic/genomic selection difficult to implement (Mrode *et al*., 2018).

We found that attitudes were influenced by education level and age. However, a different pattern was revealed depending on the country. In Spain, the higher the farmer education level, the more positive attitude towards genetic and genomic tools. In Greece age was a driver of farmer attitudes; younger farmers were more positive towards genetic/genomic breeding. Such results are consistent with findings from previous studies which showed age to be a key determinant of Greek farmers' attitude towards innovation (Andreopoulou *et al*., 2014, Kountios *et al*., 2018). Considering the above, age and education could possibly be characterized as co-dependent drivers of farmers' attitude. Certainly, the lack of access of older people to training programs about genetic/genomic breeding tools should be taken into account. This insight could be used towards designing appropriate extension activities tailored to the specific needs of different farming systems and farmers.

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Préparation d'un fromage de chèvre aromatisé avec les huiles essentielles du romarin (*Rosmarinus officinalis* L) et de l'armoise blanche (*Artemisia herba-alba* Asso) : profil sensoriel et propriétés physico-chimiques

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Résumé. Dans un objectif de proposer aux unités féminines oasiennes de transformation du lait de chèvre à l'échelle des oasis un nouveau produit laitier, un fromage de chèvre a été fabriqué par une coagulation enzymatique. L'huile essentielle (HE) des deux espèces (*Artemisia herba-alba* Asso et *Rosmarinus officinalis* L.), extraite par une hydro-distillation, a été incorporée à raison de 0,06‰ et 0,13‰. Cinq catégories de fromage ont étés obtenues : fromage non aromatisé (T), fromage aromatisé avec des doses respectives de 0,06‰ et 0,13‰ de l'HE du romarin (R0,06 et R0,13) et de l'armoise blanche (AR0,06 et AR0,13). Le profil sensoriel et les propriétés physico-chimiques de ces fromages ont étés évaluées. Les résultats montrent que l'aromatisation influence significativement (P<0,05) sur les attributs sensoriels analysés : 'apparence', 'flaveur' et 'intensité de l'arôme'. Ainsi, le profil sensoriel du fromage R0,13 a été le mieux apprécié, contrairement au fromage AR0,13. Sur le plan physico-chimique, aucune différence significative (P>0,05) n'a été constatée pour la matière grasse, le pH, les minéraux et la teneur en acide lactique pour les cinq catégories du fromage. Cependant, la couleur sur l'échelle Hunter-Lab (paramètres L* et b*) a été significativement influencée par le type du fromage. Ainsi, trois lots ont étés identifiés : [fromage T, R0,06 et R0,13], [AR0,06] et [AR0,13]. En termes de conclusion, le fromage de chèvre à base de l'HE du romarin peut constituer une source de diversification des produits laitiers commercialisés par les coopératives féminines de la zone oasienne du Sud-est marocain.

Mots-clés. Fromage – Oasis – Romarin – Armoise blanche – Physico-chimique – Sensoriel.

Flavored Moroccan goat cheese prepared with rosemary (*Rosmarinus officinalis *L.) and white wormwood (*Artemisia herba-alba *Asso) essential oils: Sensory profile and physicochemical properties

Abstract. *With the objective of providing a new dairy product to oases women's goat milk processing units, a goat cheese has been produced by enzymatic coagulation. The essential oil (EO) of both species (*Artemisia herba-alba *Asso and* Rosmarinus officinalis *L.), extracted by hydro-distillation, was incorporated at a rate of 0.06‰ and 0.13‰. Five cheese categories were obtained: unflavoured cheese (T), flavored cheese with respective doses of 0.06‰ and 0.13‰ of the EO of rosemary (R0.06 and R0.13) and white wormwood (AR0.06 and AR0.13). The sensory profile and physicochemical properties of prepared cheeses were evaluated. The results demonstrate that aromatization influences significantly (P<0.05) the analyzed sensory attributes: 'appearance', 'flavour' and 'aroma intensity'. Thus, the sensory profile of "R0.13 cheese" was highly appreciated, contrarily to "AR0.13 cheese". For the physico-chemical properties, no significant difference (P>0.05) was found for fat, pH, minerals and lactic acid content for the five categories of cheese. However, the colour on the Hunter-Lab scale (L * and b * parameters) was significantly influenced by cheese category. Thus, three batches were identified: [T – R0.06 – R0.13], [AR0.06] and [AR0.13]. In conclusion, flavoured goat cheese with rosemary EO can be used as a new dairy product marketed by women's cooperatives in the oasis regions of southern-east of Morocco.*

Keywords. *Cheese – Oasis – Rosemary – Wormwood – Physico-chemical – Sensory.*

I – Introduction

Au Maroc, les coopératives féminines ne représentent qu'environ 14% du tissu coopératif national. Ces coopératives concentrent leurs activités au développement économique (emploi et revenu) de leurs terroirs à travers des activités génératrices de revenus tel que la valorisation des produits locaux (MAES, 2017). A l'échelle des oasis, la femme occupe une place prépondérante dans le fonctionnement des unités de production vu la migration des hommes dans les régions Nord du Maroc ou à l'étranger. Ces unités féminines concentrent leurs activités dans la valorisation du lait en fromage frais uniquement malgré l'excédent laitier qui s'oriente vers l'autoconsommation (Noutfia *et al.,* 2016). Dans ce sens et dans une perspective (i) de valoriser davantage les produits locaux des oasis, dont principalement le lait de chèvre et les plantes aromatiques et médicinales (PAM), et (ii) de faire bénéficier davantage la femme rurale oasienne d'autres sources de revenus, le présent travail propose de développer un nouveau produit laitier à base du lait de chèvre et des huiles essentielles des PAM autochtones des oasis.

II – Matériel et méthodes

1. Fabrication du fromage

Le lait de la chèvre Drâa (race caprine autochtone des oasis) a été utilisé pour la fabrication du fromage à travers une coagulation enzymatique. Les échantillons du lait ont étés prélevés de la station expérimentale d'Errachidia à raison de 8 litres par fabrication. L'huile essentielle (HE) des espèces *Artemisia herba-alba Asso* et *Rosmarinus officinalis L.* a été extraite par une hydro-distillation au laboratoire et a été incorporée à raison de 0,06‰ et 0,13‰. Cinq catégories de fromage ont étés développées : fromage non aromatisé (T), fromage aromatisé avec 0,06‰ et 0,13‰ de l'HE du romarin : (R0,06) et (R0,13),fromage aromatisé avec 0,06‰ et 0,13‰ de l'HE de l'armoise blanche : (AR0,06) et (AR0,13).

2. Evaluation du profil sensoriel

Pour cette analyse, sept panélistes semi entrainés ont évalués le profil sensoriel des fromages élaborés. Cette évaluation a été faite sur une échelle hédonique de 0 à 5 pour les attributs : flaveur, intensité de l'arôme et apparence.

3. Analyses physico-chimiques

Ces analyses ont porté sur la détermination du pH, acidité Dornic, matière grasse, cendres et couleur sur l'échelle chromatique L* (Luminance), a* (Echelle de rouge) et b* (Echelle de jaune). Toutes ces analyses ont été réalisées avec trois répétitions selon les normes internationales.

III – Résultats et discussion

1. Evaluation des profils sensoriels des fromages aromatisés

Le profil sensoriel des différents fromages aromatisés est reporté dans la Table 1.

Table 1. Effet de l'aromatisation sur l'acceptabilité des fromages à base du lait de chèvre

Fromage	Apparence	Sensation à la bouche	Intensité arôme
Nature	4,26 [a,b]	3,64 [a,b]	2,09 [a]
R 0,06‰	4,25 [a,b]	4,04 [a,b]	3,36 [c]
R 0,13‰	**4,37 [a]**	**4,17 [a]**	3,81 [b,c]
AR 0,06‰	3,89 [b]	3,79 [a,b]	3,96 [b,d]
AR 0,13‰	3,94 [a,b]	3,48 [b]	4,34 [d]

D'une manière générale, l'aromatisation influence significativement (P<0,05) les trois attributs proposés pour cette analyse sensorielle. Cependant, cette aromatisation ne semble pas affecter de la même manière ces attributs. Par rapport au fromage non aromatisé, l'incorporation de l'HE du Romarin améliore considérablement la flaveur du fromage contrairement à l'HE de l'armoise blanche. Le même constat peut être généralisé pour l'attribut «apparence». L'intensité de l'arôme a été beaucoup plus prononcée pour le fromage AR0,13. Ainsi, le score obtenu pour cet attribut augmente avec la dose de l'HE et en passant du romarin à l'armoise blanche. Comparativement à d'autres travaux, Josipović *et al.,* (2015) rapportent que la qualité sensorielle du fromage blanc est améliorée en incorporant des herbes frais et séchés du romarin et du persil. De même, l'incorporation de l'HE de l'origan améliore la flaveur et l'arôme d'un fromage traditionnel de l'Argentine (Marcial *et al.,* 2016). Il a été rapporté que l'apparence des fromages aromatisés est toujours liée à la brillance et à l'humidité de la surface (Asensio *et al.,* 2014). Ainsi, un faible score attribué à cet attribut (apparence) s'explique par des défauts liés au dégagement des gouttelettes d'eau à la surface du fromage et à une brillance non appréciée. Ceci permet de déduire que le fromage AR0,06 est beaucoup plus susceptible à la génération de ce type de défauts, contrairement au fromage R0,13. Pour le contexte marocain, nos résultats sont en désaccord avec les obtentions de Zantar *et al.* (2013) qui ont révélés une préférence des dégustateurs du fromage non aromatisé par rapport aux fromages aromatisés.

2. Composition physico-chimique des fromages

Les paramètres physique et chimique des fromages aromatisés sont donnés dans la Table 2.

Table 2. Valeurs moyennes de quelques paramètres physico-chimiques des fromages aromatisés

Fromage	pH	Acidité (g/kg)	MG (%)	Cendres (%)	L*	a*	b*
Nature	4,55 [a]	6,50 [a]	19,5 [a]	1,48 [a]	83,3 [a,b]	-0,79 [a]	16,1 [a,b]
R 0,06‰	4,60 [a]	6,80 [a]	18,1 [a]	1,50 [a]	83,7 [a,b]	-0,76 [a]	15,7 [a,b]
R 0,13‰	4,58 [a]	6,57 [a]	17,9 [a]	1,42 [a]	84,3 [a,b]	-0,81 [a]	15,7 [a,b]
AR 0,06‰	4,59 [a]	6,23 [a]	19,1 [a]	1,63 [a]	85,3 [a]	-0,86 [a]	16,9 [a]
AR 0,13‰	4,62 [a]	6,43 [a]	19,0 [a]	1,43 [a]	83,0 [b]	-0,87 [a]	15,3 [b]

Le pH des cinq catégories de fromage varie (P>0,05) entre 4,55 et 4,62. Ce pH est comparable au fromage frais aromatisé par les huiles essentielles, avec des doses de 0,5‰ et 1‰, du Thym et d'Origan (Zantar *et al.,* 2013 ; Zantar *et al.,* 2014). Pour l'acidité, la teneur en acide lactique varie entre 6,23‰ pour le fromage aromatisé avec l'Armoise à 6,80‰ pour le fromage aromatisé avec le Romarin. Par rapport au témoin, le tableau 2 montre que l'aromatisation avec l'HE du Romarin semble augmenter légèrement l'acidité (6,57-6,80‰) du fromage, contrairement à l'HE de l'Armoise (6,23-6,43‰).

La fraction grasse (MG) et minérale (cendres) des fromages ne semblent pas être influencée statistiquement (P>0,05) par l'incorporation des huiles essentielles. Cependant, cette aromatisation semble diminuer la teneur en matière grasse. Ainsi, des valeurs légèrement inférieures à la MG du témoin (19,5%) ont étés obtenues pour les fromages aromatisés. Ces observations peuvent témoigner d'une douce lipolyse pour les fromages aromatisés. D'une manière générale, le profil en MG concorde avec l'étude de Foda *et al*. (2010).

Pour la couleur, sur l'échelle chromatique L*a*b*, il ressort que l'incorporation des huiles essentielles influence significativement (P<0,05) sur les paramètres L* et b*. Le paramètre a* ne semble pas être affecté par l'aromatisation. En plus, les valeurs maximales et minimales de L* et b* ont étés observées pour les fromages (à base de l'Armoise) AR0,06 et AR 0,13 respectivement. En effet, le fromage aromatisé avec une concentration élevée en HE de cette espèce aura une couleur moins blanche. La diminution de la valeur de L* est traduite par une variation de la couleur entre 'le blanc brillant' et 'le jaune terne' (Özsunar, 2010). Ce changement de couleur est le signe d'une perte d'eau/déshydratation (Akbulut, 2007 ; Özsunar, 2010). Des études montrent que l'incorporation des huiles essentielles dans le fromage permet d'augmenter sa capacité d'égouttage, en donnant des gels plus compacts avec des teneurs en eau relativement faible par rapport au fromage non aromatisé (Akarca *et al.,* 2016). Ceci concorde avec les résultats de ce travail pour le fromage aromatisé avec l'armoise blanche.

IV – Conclusions

En guise de conclusion, il ressort que l'aromatisation du fromage avec l'huile essentielle du romarin avec une dose de 0,13‰ permet une amélioration notable de la perception du fromage de chèvre de part sa flaveur et son apparence. Cette catégorie de fromage peut être adoptée et commercialisée par les coopératives féminines de la zone oasienne du Sud-est marocain dans une perspective de diversifier leurs productions et améliorer leurs revenus.

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Dietary inclusion of whole pomegranate by-product to improve oxidative stability of lamb meat

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Abstract. This study evaluated the effect of dietary whole pomegranate by-product (WPB) on the oxidative stability of lamb meat. Seventeen Comisana lambs were divided into two groups and fed for 36 days: a barley-corn based concentrate diet (CON) or the same concentrate as the CON diet containing 20% of WPB to partially replace barley and corn (WPB). The dietary treatment did not affect the growth performance of lambs. Colour descriptors and metmyoglobin percentages were measured on *longissimus dorsi* (*LD*) muscle over 7 days of refrigerated storage. Lipid oxidation (TBARS values) was measured over time of refrigerated storage in raw and cooked muscle slices (7 days and 4 days, respectively). The dietary WPB increased the concentration of α-Tocopherol in *LD* ($P < 0.001$). Colour stability descriptors (*a**, *b** and *H**) were affected by storage time, but not by dietary treatment. Metmyoglobin accumulated over time ($P < 0.001$), but WPB diet tended to decrease the overall metmyoglobin percentages ($P = 0.051$). TBARS values increased with time of storage ($P < 0.001$). WPB group showed lower TBARS values in cooked meat ($P < 0.05$). A significant interaction between dietary treatment and storage time was found for the TBARS value in raw meat ($P = 0.013$), with lower values found for WPB at 7 days of storage. The results highlight the positive effect of feeding lambs with WPB on meat shelf-life and demonstrate, for the first time, the contribution of α-Tocopherol (vitamin E) to this effect.

Keywords. Lamb – Oxidative stability – Pomegranate – Meat.

Inclusion alimentaire du sous-produit de grenade entière pour améliorer la stabilité à l'oxydation de la viande d'agneau

Résumé. *Cette étude a évalué l'effet du sous-produit alimentaire de grenade entière (WPB) sur la stabilité à l'oxydation de la viande d'agneau. Dix-sept agneaux Comisana ont été divisés en deux groupes et nourris pendant 36 jours: un régime concentré à base d'orge-maïs (CON) ou le même concentré contenant 20% de WPB pour remplacer partiellement l'orge et le maïs (WPB). Le traitement diététique n'a pas affecté les performances de croissance. La couleur et les pourcentages de métmyoglobine ont été mesurés sur le muscle longissimus dorsi (LD) pendant 7 jours de stockage au réfrigérateur. L'oxydation des lipides (TBARS) a été mesurée en fonction du temps de stockage au réfrigérateur dans des tranches de muscle crues et cuites (7 jours et 4 jours, respectivement). Le WPB alimentaire a augmenté la concentration d'α-tocophérol dans le LD (P <0,001). Les descripteurs de stabilité de la couleur (a *, b * et H *) ont été affectés par la durée de conservation, mais non par le traitement alimentaire. La métmyoglobine s'est accumulée au fil du temps (P <0,001), mais le régime alimentaire du WPB avait tendance à diminuer les pourcentages globaux de la métmyoglobine (P = 0,051). Les valeurs TBARS ont augmenté avec la durée de stockage (P <0,001). Le groupe WPB a montré des valeurs TBARS plus faibles dans la viande cuite (P <0,05). Une interaction significative entre le traitement diététique et la durée de conservation a été observée pour la valeur TBARS dans la viande crue (p = 0,013), les valeurs les plus faibles ayant été trouvées pour la gale blanche à 7 jours de stockage. Les résultats mettent en évidence l'effet positif de l'alimentation des agneaux avec du WPB sur la durée de conservation de la viande et démontrent, pour la première fois, la contribution de l'α-tocophérol (vitamine E) à cet effet.*

Mots-clés. *Agneau – Stabilité à l'oxydation – Grenade – Viande.*

I – Introduction

The use of *ecological leftovers*, such as by-products from the agro-industry, for ruminant feeding could generate several advantages in terms of sustainability, and it has also been demonstrated that most of these biomasses improve important quality traits of meat when fed to animals (Salami *et al*., 2019). This applies, for instance, to the wastes from the industrial production of pomegranate juice, which has remarkably increased in recent years. Residual portions of the fruits (peels, seeds and part of the arils) compose the "whole pomegranate by-product" (WPB), which is therefore rich in bioactive compounds among which polyphenols, other antioxidant compounds and polyunsaturated fatty acids. We recently demonstrated that the partial replacement of cereals with 20% WPB in diets for lambs increased the content of desirable health promoting PUFA in meat (Natalello *et al*., 2019). Other authors reported positive effects of feeding different pomegranate by-products to ruminants on meat oxidative stability and mainly attributed these effects to the polyphenols (Emami *et al*., 2015a; 2015b). Nevertheless, pomegranate seed oil contains fat-soluble antioxidants which could contribute to the antioxidant effects of WPB. Therefore, the objective of this study was to assess the effects of dietary WPB on the oxidative stability of lamb meat, with a focus on antioxidant compounds other than polyphenols.

II – Materials and methods

1. Animals and diets

The experiment was conducted at the experimental farm of the University of Catania. Comisana male lambs (n=17, 14.82 kg ± 2 kg body weight) were individually housed indoors. After an 8-day adaptation to the experimental diets, lambs were fed *ad libitum* for 36 days: a pelleted barley/corn-based diet (CON, n=8) or the same diet in which 200 g/kg DM of WPB partially replaced barley and corn (WPB, n=9). The fresh WPB containing peels, seeds and residual aril pulp, was dried at 40°C. The amount of offered and refused diet was recorded daily, while bodyweight was measured weekly.

2. Samplings and analyses

Lambs were slaughtered at a commercial abattoir according to the European guidelines. Each carcass was immediately weighted and stored at 4° C for 24 h. The *longissimus dorsi* muscle (LD) was excised and one portion was immediately vacuum-packed and stored at ! 80 °C for vitamin E analysis, while the other was aged vacuum-packaged for 3 days at 4 °C and used for oxidative stability measurements. Vitamin E (α-Tocopherol) in feedstuffs and muscle was analysed as described in detail by Valenti *et al*. (2018), using an HPLC system equipped with a fluorescence detector. The oxidative stability was monitored in raw and cooked LD slices using the storage conditions and analyses detailed by Valenti *et al*. (2018). Briefly, three slices were cooked vacuum-packaged for 30 min at 70°C in a water bath. One of these was used immediately for measurement of lipid oxidation (day 0), whereas the other two slices were placed in polystyrene trays, over-wrapped with PVC film and stored at 4 °C for lipid oxidation analysed after 2 and 4 days. The other three slices were stored raw in the same conditions as cooked meat for 0 (after 2 hours of blooming), 4 and 7 days. At the end of respective storage time, colour was measured in duplicate on each raw meat slice by a Minolta spectrophotometer. The colour descriptors L* (lightness), a* (redness), b* (yellowness), C* (saturation) and H* (hue angle) were measured in the, while the reflectance spectra from 400 to 700 nm wavelength were recorded for calculation of metmyoglobin (MMb, % of total myoglobin). For both raw and cooked meat, lipid oxidation was measured as TBARS values (mg/kg of meat).

Data on muscle vitamin E concentration were analysed using a GLM model to test the effect of the Diet (CON *vs*. WPB). Oxidative stability parameters were analysed using a GLM model to test the

fixed effects of Diet, Time of storage (days 0, 4, 7 or 0, 2, 4) and Diet × Time interaction. The model included the individual animals as random effect nested with the Diet. The Tukey's test was used for multiple comparisons.

III – Results and discussion

For the same animals used in the present study, Natalello *et al*. (2019) reported no effect of the feeding the WPB diet on the main performance parameters (daily bodyweight gain, carcass weight and feed intake). Also, as commented above, the WPB treatment resulted in a higher concentration of total polyunsaturated fatty acids (PUFA) in meat, with a specific effect on some individual health-promoting compounds (Natalello *et al*., 2019). If a higher content of PUFA in meat is desirable from a nutritional perspective, a possible drawback may be represented by the greater susceptibility of PUFA to oxidation, which in turn reduces the resistance of meat to lipid oxidation and colour deterioration. This applies to conditions in which PUFA increase in muscle without a concurrent greater deposition of antioxidants, among which vitamin E plays a major role (Ponnampalam *et al.*, 2014). Nevertheless, in the present study, we found that the colour stability descriptors were not affected by the dietary treatment, but were only subjected to the changes usually observed in meat over time of storage or display (Table 1). Specifically, a* values decreased over the 7-day storage time indicating the loss of redness, while increases in b* and H* reflected meat browning, consistently with the increase in the percentage of metmyoglobin (MMb%) with time. Additionally, the WPB diet tended to reduce the overall MMb% (lower oxidation of myoglobin) in meat, which suggests an antioxidant effect of pomegranate by-product. However, the differences in MMb% were numerically minimal and, probably, not sufficient to produce appreciable effects on the colour descriptors.

Table 1. Effect of the diet and time of storage on meat oxidate stability

	Diet (D)		Time of storage (T)[1]			SEM	*P*-values		
	CON	WPB	0	1	2		D	T	D × T
Colour descriptors and Metmyoglobin of raw meat									
a*	11.6	11.6	12.2^{a}	11.6^{ab}	10.9^{b}	0.166	0.929	<0.00	10.181
b*	11.2	11.4	10.2^{b}	11.9^{a}	11.9^{a}	0.194	0.663	<0.00	10.159
H*	44.1	44.3	39.6^{c}	45.6^{b}	47.5^{a}	0.494	0.620	<0.00	10.087
MMb %	47.6	46.0	39.5^{c}	49.2^{b}	51.3^{a}	0.762	0.051	<0.00	10.498
TBARS values in raw and cooked meat, mg/kg meat									
Raw	0.95	0.56	0.25^{b}	0.80^{a}	1.08^{a}	0.080	0.024	<0.00	10.013
Cooked	3.74	3.07	1.69^{c}	3.60^{b}	4.70^{a}	0.192	0.006	<0.00	10.266

[1]Times 0, 1, 2 indicate respectively: days 0, 4, 7 (raw meat), or 0, 2, 4 (cooked meat).

The results of the present study clearly showed that feeding the WPB diet improved the resistance of meat to lipid peroxidation, with lower TBARS values being found overall in meat from WPB-fed lambs over storage duration in both raw and cooked meat ($P < 0.05$; Table 1). Also, the Diet × Time interaction found for TBARS values of raw meat revealed a lower rate of lipid oxidation development in meat from lambs fed the WPB diet, which brought to lower TBARS values after 7 days of storage compared to CON ($P < 0.05$; Fig. 1a). These results are consistent with previous reports demonstrating that feeding different pomegranate by-products to ruminants improved the antioxidant status and oxidative stability of meat (Kotsampasi *et al*., 2014; Emami *et al*., 2015a; 2015b). However, the authors mainly attributed these effects to the occurrence of phenolic compounds in pomegranate fruits and did not determine the content of vitamin E and other fat-soluble antioxidants in feeds and muscle. Only Shabtay *et al*. (2008) reported greater content of vitamin E in the blood of calves, but meat oxidative stability was not studied. In the present study, feeding the WPB diet produced a greater deposition of α-tocopherol in muscle (Fig. 1b). This result can be explained to

the greater content of this molecule in the WPB diet compared to CON (16.8 vs 7.8 mg/kg DM, respectively; data not shown), which was likely due to the occurrence of vitamin E in pomegranate seeds. Therefore, the higher concentration of vitamin E in meat from the WPB-fed lambs may have at least partially increased the oxidative stability of meat compared to CON.

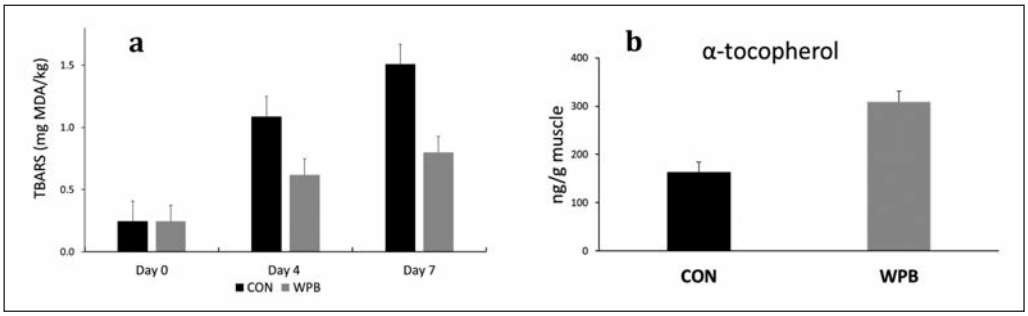

Fig. 1. Lipid oxidation (a) and α-tocopherol content (b) in raw meat.

IV – Conclusions

The results of this study demonstrated that replacing conventional feedstuffs with whole pomegranate by-product in diets for lambs allows improving meat quality traits without compromising productive performances. Specifically, here we found that meat from lambs fed the WPB diet was more resistant to oxidation, despite the greater content of PUFA previously reported. Also, our results suggest, for the first time, that α-tocopherol contributes to the antioxidant capacity of meat from animals fed pomegranate by-product.

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Demographic performance of local sheep and goat breeds in two agro-ecological zones in Egypt

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Abstract. Small breeders in Egypt raise locally adapted sheep and goats breeds, which have the ability to produce and reproduce under the prevailing harsh conditions. Improving resilience of their production system is a major challenge to support socioeconomic development. However, little is known about the productive abilities of these breeds in small farming systems. The present work is an attempt to assess the performance of local breeds in small farming systems, and their capacity to cope with feed scarcity and harsh climatic conditions. In 2018, a retrospective survey was conducted over 12 month period to assess demographic rates of 25 local Barki sheep and goat flocks in the rain-fed area of Coastal Zone of Western Desert (CZWD) and 28 local Saidi sheep and goat flocks under the hot intensive agriculture system in Upper Egypt (UE). Flocks are larger, reproductive performance and offtake rates are higher (and mortality lower) in the CZWD, a region specialized in small ruminant breeding whereas it remains a secondary activity in Upper Egypt. The marketing season is mainly during Korban Eid festival. Their main challenges are frequent incidence of drought in the CZWD and high prices of feed stuffs in both sites. Our study suggests breeders have different strategies in UE and the CZWD when confronted with feed shortage. Breeders in the CZWD purchase feed to maintain high herd productivity whereas in UE small ruminant breeding is a minor activity with less productive animals that are resilient to feed shortage.

Keywords. Local breed – Barki – Saidi-Egypt – Performance.

Performance démographique des races locales ovines et caprines dans deux zones agro-écologiques de l´Egypte

Résumé. *Les races locales de petits ruminants élevées en Egypte sont reconnues pour leur la capacité à demeurer productives malgré des conditions climatiques extrêmes. L'amélioration de la résilience des systèmes d'élevage est un défi majeur pour le développement socioéconomique. Cependant, les performances démographiques de ces races n'ont à ce jour pas été caractérisées en conditions réelles. Ce travail présente les premiers résultats d'une étude sur les performances de ces races dans deux régions d'élevage contrastées en Egypte. En 2018, des enquêtes démographiques rétrospectives sur les 12 derniers mois ont été effectuées sur 25 troupeaux de moutons et chèvres Barki dans la zone pastorale côtières et sur 28 troupeaux de moutons et de chèvres Saidi le long de la vallée du Nil en Haute Egypte, une région historique d'agriculture intensive. La fertilité et les taux d'exploitations sont plus élevés en zone pastorale (et la mortalité moindre) vraisemblablement en raison de la spécialisation de cette région dans l'élevage alors qu'il s'agit d'une activité secondaire en Haute Egypte. Le gros des ventes se déroule pendant les fêtes religieuses de Korban Eid. Les principaux défis sont la récurrence des sécheresses dans la zone pastorale et les coûts élevés des aliments dans les deux sites. Nos résultats suggèrent une stratégie différente des éleveurs confrontés au manque de fourrage. Dans la zone pastorale côtière, les éleveurs maintiennent la productivité du troupeau en achetant de l'aliment tandis qu'en Haute Egypte l'élevage de petits ruminants est une activité mineure avec des animaux moins productifs mais résilient au manque de fourrage.*

Mots-clés. *Races locales – Barki – Saidi, Egypte – Performance.*

I – Introduction

Small breeders in Egypt raise locally adapted sheep and goats breeds under intensive or extensive systems in different agro-ecological zones. The breeds have the ability to produce and reproduce under the prevailing harsh conditions. They play an important socio economic role by constituting a capital that can serve as a source of food or cash in times of need (e.g. dowry in marriages, social events...). Sheep and goats are raised mainly for meat production, with coarse wool and goat milk as secondary products. Breeders face numerous challenges such as human demographic growth, increasing demand on animal products, competition for land, climate stress and market price fluctuations. There is little information about the productive capability and dynamics of these breeds in small holder farming systems.

The identification of animals and the routine collection of animal data are rare in Egypt for small farmers. In the absence of written records, retrospective surveys provide a quick diagnostic tool to determine the demographic characteristics of flocks. The present work is an attempt to assess the annual performance of these local breeds, their capacity to cope with feed scarcity and harsh environmental conditions, in the two agro-ecological zones for the period of 2017-2018.

In Egypt, two of the main small ruminant production systems are the Upper Egypt (UE) intensive agriculture system and extensive Coastal Zone of Western Desert (CZWD) pastoral system. In Upper Egypt, the intensive cultivation of winter and summer crops is concentrated in a narrow strip of irrigated land along the Nile River that produces economic crops as well as feed for animals. The agriculture production system is intensive on small areas of land of around 1 feddan (≈1 acre) with1-2 large ruminants and 1-5 small ruminants for each household. Local breeds adapted to extreme temperatures are Saidi sheep and goats.

In the Coastal Zone of Western Desert, the Bedouins mostly rely on raising sheep, goats and camels; they also cultivate barley and grow olive and figs trees. Extensive livestock breeding depends on rain fed natural pastures. Local breeds are Barki sheep and goats, which have the ability to move over rough terrain to feed on sparse desert vegetation. Sheep flock size ranges from 15 heads to more than a thousand animals and goat herds between 5 and 200 animals. The mixed sheep and goat flocks use the available rangelands during winter and early spring, however the contribution of natural pastures to the feed requirements of the animals has been decreasing over the last decades due to successive years of drought.

II – Materials and methods

1. Study areas

Matrouh belongs to the Coastal Zone of Western Desert which extends from Alexandria to the Libyan border. It is characterized by an arid Mediterranean climate with annual rainfall below 150 mm between mid-October and mid-March. Temperatures range from maximum 36°C in July to minimum 6ºC in January.

Assiut is located in Upper Egypt along the Nile River. The weather is hot with maximum temperature over 40°C and minimum 3°C; annual rainfall is negligible.

2. Retrospective demographic survey

The 12MO method (Lesnoff *et al*., 2010) consists in categorizing all the animals in a herd by age and sex and listing the demographic events (births, natural deaths, slaughtering, loans, purchases, etc.) that occurred over the last twelve months. We conducted 12MO surveys between September 15th and 20th 2018 in Matrouh just after El-Eid festivities and from November 14th to 17th

2018 in Assiut just after berseem clover was sown. Memorable dates were chosen to ensure the breeder accurately recorded events over the last 12 months. Fifty-two breeders were surveyed (25 Matrouh + 27 Assiut) amounting to 1371 heads (753 Barki + 618 Saidi) of sheep. For goats, the total number of breeders was 30 (11 Matrouh + 19 Assiut) amounting to 308 heads (141 Barki + 167 Saidi). The size of studied flocks in Matrouh ranged between 15 to 45 heads of sheep and 5 to 22 goats, whereas in Assiut it ranged between 5 and 15 sheep and 3 to 10 goats.

In the absence of longitudinal surveys, 12MO approach provides demographic rates with only one visit per flock and can be applied to all farming systems. It is a quick and efficient method to estimate herd performance. The main limitations are possible biases in demographic rates when the breeder forgets to mention births, deaths or sales. The survey only considers the past 12 months and cannot account for fluctuations in demographic rates between years. To limit investigative bias, we hypothesized that large flocks had similar demographic performance to medium sized flocks, we sampled flocks with less than 60 reproductive females and always conducted interviews in presence of the animals and the shepherd or breeder in charge of rearing them.

3. Estimation of demographic parameters

Demographic parameters (parturition, abortion, off-take and mortality) are presented as instantaneous hazard rate (*h*) (Lesnoff *et al* 2010); *h* can be calculated for each category of animals as:

$$h = \frac{m}{T} \qquad \text{(eq. 1)}$$

Where *m* is the number of events (e.g. number of deaths) that have occurred in the last 12 months, and T is the total 'time at risk' (time spent by animals for a given category in the herd over the last 12 months). Hazard rates were calculated separately by site, species, sex and age class (young < 1 year, adult > 1 year). Hazard rates were estimated using the 12MO package (http://livtools.cirad.fr/12mo) in R version 3.5.3.

III – Results

Parturition rate of both sheep and goats was higher in Matrouh than in Assiut. For both species, offtake rates were higher and mortality rates lower in Matrouh than Assiut, with the exception of adult males because breeders keep very few reproductive males.

Table 1. Parturition and abortion hazard rates

			Parturition		Abortion	
Species	**Site**	**n. adult females**	**n. event**	**h±se**	**n. event**	**h±se**
Goats	Assiut	89	72	0.82±0.09	6	0.07±0.007
	Matrouh	101	93	0.95±0.09	6	0.06±0.006
Sheep	Assiut	408	308	0.76±0.04	12	0.03±0.001
	Matrouh	572	540	0.98±0.04	22	0.04±0.002

The off take rate for young (< 1 year) Barki males and females (2.82 and 1.78, respectively) in Matrouh was high when compared to the same age class of Saidi sheep in Assiut (1.97 and 0.83, respectively). The same could be found for goats, as the off-take rates for young Barki males (2.75) and females (1.8) were higher than off-take rates of young Saidi males (0.75) and females (0.70). In Assiut, there were high mortality rates for young sheep and goats for both males and females when compared to the mortality rates of young sheep and goats in Matrouh. The mortality rates for adult sheep and goats in both sites were low (Table 2).

Table 2. Offtake and mortality hazard rates

					Offtake		Mortality	
Species	**Site**	**Sex[1]**	**Age class[2]**	**n. animals**	**N. event**	**h±se**	**N. event**	**h±se**
Goats	Assiut	F	A	89	13	0.14±0.04	1	0.01±0.01
		F	Y	25	17	0.70±0.17	24	0.99±0.20
		M	A	14	8	0.51±0.18	0	–
		M	Y	39	23	0.75±0.16	13	0.42±0.12
	Matrouh	F	A	101	8	0.08±0.03	3	0.03±0.02
		F	Y	21	49	1.8±0.26	3	0.11±0.06
		M	A	4	0	–	0	–
		M	Y	15	79	2.75±0.31	6	0.21±0.09
Sheep	Assiut	F	A	408	34	0.08±0.01	24	0.06±0.01
		F	Y	119	79	0.83±0.09	43	0.45±0.07
		M	A	33	24	0.64±0.13	1	0.03±0.03
		M	Y	58	168	1.97±0.15	40	0.47±0.07
	Matrouh	F	A	572	89	0.15±0.02	33	0.06±0.01
		F	Y	104	262	1.78±0.11	33	0.22±0.04
		M	A	34	5	0.16±0.07	0	–
		M	Y	43	361	2.82±0.15	51	0.39±0.06

[1]*Sex:* F: Female, M: Male, [2]*Age class:* A: Adult (>1 year), Y: Young (<1 year).

III – Discussion

In Matrouh, most Barki ewes give birth twice per year and this is in accordance with previous studies by Galal *et al* (2005). Bedouin breeders inherit their flock from their ancestors and have great experience of rearing animals in harsh desert conditions. They are specialized in small ruminant breeding which is their main source of income. Keeping high parturition rates is paramount to maintain their revenue, leading breeders to supplement females during the years of drought for them to produce offspring more than once per year. Lower parturition rates in Assiut may result from the lower importance of small ruminants in Upper Egypt. Farmers with land mainly rely on cultivating their land throughout the year by using irrigation from the Nile, and landless farmers struggle to provide feed for their flock (Alary *et al*., 2015). Saidi sheep and goats are less valued than large ruminants and only have access to left over crop residues and smaller amounts of concentrates. As a result, lack of feed may partly explain the differences in parturition rates between Assiut and Matrouh. In addition, Barki breeds may have been selected to be inherently more prolific than Saidi that are kept in smaller herds and for which less attention is given to reproductive performance but resilience to feed shortage is paramount.

Young lambs and kids (<1 year) have the highest mortality rate in both sites and both sexes. This may be due to lack of feed, lack of veterinary care, harsh climatic conditions and transboundary diseases in Matrouh. Galal *et al* (2005) reported mortality rate of Barki lambs from birth till 4 months was 6.3 % to 16.6%. The mortality rate of young animals in Assiut was higher than Matrouh and this also may be due to non-specialized management in a mixed production system.

Selling and slaughtering rates were very high for young lambs for males and females in both sites. Selling young animals is necessary for breeders to purchase feedstuffs to feed their flock and veterinary medicine to maintain a core breeding herd of reproductive females. In Matrouh, there is also high market demand on young lambs, as it is preferable for the consumer because lambs have a lean carcass. There was a high selling rate for young males and females compared to Assiut.

High levels of offtake observed in both sites may reflect a drought coping strategy by reducing flock size without affecting reproductive outputs. Alary *et al* (2014) indicated that the breeders in Matrouh usually sell sheep and goats to face drought to maintain their reproductive animals and to cover their family needs. However, this hypothesis remains to be confirmed by comparing the rates measured in 2018 (a particularly dry year in the CWDZ) with years of higher rainfall and pasture productivity.

IV – Conclusions

The last twelve month method is used to roughly evaluate animal performance in small to medium flocks. However, estimated parameters should be interpreted with caution. The two studied agro-ecological zones showed similar parameters for mortality and selling rates for both sheep and goats. Only the parturition rate was higher in Barki compared to Saidi. Our study suggests breeders have different strategies in Assiut and Matrouh when confronted to feed shortage. In Matrouh, family livelihoods depend on small ruminant breeding (especially sheep) particularly during droughts due to lack of revenue from other agricultural activities (barley, olives and figs). Breeders purchase feed to maintain high productivity and sell the lambs and kids to buy food for people and feed for animals. In Assiut, irrigated agriculture provides the main livelihood, and small ruminants are secondary. They feed on left over crop residues and concentrates, Saidi breeds are less productive but may be more resilient to feed shortage. Further experimental work is needed to compare Saidi and Barki breeds under similar climatic conditions and feed rations to disentangle environmental and genetic contributions to animal performance.

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Sheep farming systems and management options under semi arid conditions: case of Saouaf farm in Tunisia

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Abstract. The study was conducted at the farm of Saouaf belonging to the Office de l'Elevage et de Pâturage (OEP). Five sheep flocks are hosted at the farm represent two local breeds namely Barbarine or fat tailed, structured in four flocks (2 representing the black head and other 2 representing the white head types), and West thin tailed structured in one flock. The main objective of the present study was to highlight management options of the flocks, reproduction parameters and strategies of amelioration followed by OEP. All parameters of reproduction (fertility, prolificacy, fecundity, etc) were low especially for Barbarine breed. Productivity (weaned lambs/mated ewes) for both breeds was low (<100%). Artificial insemination application was traduced by an increase of prolificacy and other parameters. Results of the present study suggest that technical training of shepherds is the success key of breeding in the farms of Saouaf. Other factors such as selection of breeding rams either towards natural mating or for artificial insemination could be a useful tool to enhance productivity in both breeds.

Keywords. Sheep – Reproduction – Growth-performances – Barbarine.

Systèmes de production ovine et option de son management sous des conditions de semi-aride: cas de Saouaf

Résumé. *Cette étude a été menée dans la ferme de Saouaf qui appartient à l'Office de l'Elevage et de Pâturage (OEP). Le suivi de la ligne de conduite, les paramètres de reproduction et le calendrier fourrager ont été portées sur cinq troupeaux (Barbarine et Queue fine de l'Ouest) et ce depuis 2011/12 jusqu'à 2016/17. Les résultats de paramètres zootechniques sont considérés faibles et ne répondent pas aux normes. La formation technique des bergers pour le suivi correcte du troupeau est nécessaire afin d'améliorer la productivité du troupeau. D'autres tentatives d'amélioration telles que le recours à l'insémination artificielle et la création d'un centre d'élevage bélier semblent être une voie prometteuses pour améliorer la productivité du troupeau.*

Mots-clés. *Ovin – Reproduction – Performances de croissance – Barbarine.*

I – Introduction

In Tunisia, sheep breeding sector is characterized by large variety and repartition in the different parts of the country. Animals of local breeds (Barbarine, West thin tailed and black of Thibar) are raised mainly (95%) for meat production, and to a small extent (5%) for milk production (Sicilo Sarde). In 2017 the national inventory was registering about 7 million heads, from which 3.737.000 were breeding females (OEP, 2017), and raised by 274.000 breeders. Sheep breeding is mainly located in the country's northern (41%) and the central regions (42%). Nowadays, sheep contribute to 42% of the total national red meat production (120.000 tones/year), while cattle contribute equally (43%). The main objective of the present study was to investigate mating management options and the evolution of animal performance (reproduction parameters and average daily gains, ADG) of lambs in the farm of Saouaf during six consecutive years.

II – Material and methods

The farm belongs to Office d'Elevage et des Pâturages (OEP), located in Saouaf region (government of Zaghouan) in the south of Dorsal Tunisian chain mountains. It covers 1523 ha from which 639 ha are cultivated rangelands (acacia, spinless cactus, atriplex, etc.) and 182 ha natural rangelands. It is a semi arid region (precipitation varied between 200-400 mm/year). Livestock production is based on sheep and goats breeding. The total sheep inventory is estimated to 1044 heads in 2017, subdivided in 5 flocks composed of two local breeds: four flocks are Barbarine (50% black head and 50% white head) called also the fat tailed, and one flock is of West thin tailed breed. Goats, a cross-breeding between Boer and Damask breeds, are regrouped in one flock composed by 224 breeding females. Based on reported data on lambing (Table 1), reproduction parameters (fertility, fecundity, prolificacy, productivity, etc) were calculated on six consecutive years (2011/2012-2016/2017) as follow:

- Fertility rate = (lambing ewes/matted ewes)*100;
- Prolificacy rate = (born lambs/lambing ewes)*100;
- Fecundity rate = (born lambs/mated ewes)*100;
- Lamb mortality = mortality in lambs/born lambs;
- Adult mortality = (mortality in ewes/mated ewes)*100;
- Productivity rate = (weaned lambs/mated ewes)*100

Table 1. Data reported on lambing in Saouaf farm during the study years

Items	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Mated ewes	1319	1167	1027	1046	1002	1044
Lambing ewes	1054	971	893	901	822	807
Born lambs	1100	1011	1066	982	953	929
Mortality in lambs	70	32	51	30	31	53
Mortality in ewes	120	78	58	75	37	93

Lambs were individually weighed at two periods and average daily gain (ADG) was calculated, at 10-30 days (ADG_{10-30}) and at 30-70 days (ADG_{30-70}). Growth data were also used for selection purposes.

III – Results and discussion

1. General overview on flock size and land occupation of the farm

Data on the evolution of the total inventory of sheep in Saouaf farm is presented in Table 2. A continuous decrease was recorded in the course of the study, estimated at about 21%, which was more pronounced for the Barbarine breed. This trend was against the strategic aim of the farm to increase flock size through buying the parts of the shepherds, after a structured selection process. This decrease is attributed to the prolonged drought period that was recorded for four consecutive years (2012-2016) and resulted in a sharp decline in forage production, recorded at national level during this period (OEP, 2017).

Table 2. Evolution of the sheep inventory in farm Saouaf during the study years

Breeds	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Barbarine	1122	980	859	858	813	841
West fine tailed	197	187	168	188	189	203
Total	1319	1167	1027	1046	1002	1044

Cereal and forage production is a second activity highly developed in the farm Saouaf. Data on the average forage cultivated area and yield production in the farm is presented in Table 3.

The largest area is occupied by oat for hay (200 ha), which is a common forage in this country. In our farms, oat hay constitutes a basal diet for animals all year round (Table 3). The average yield is at about 40 t (fresh material/ha, which is considered in the norms, but hay has a low nutritional value (0.4 UF/kg DM) (Ammar, unpublished data).

Table 3. Forage and cereal grain annual production in the farm of Saouaf

	Barley (grains)	Oat (grains)	Medic (seeds)	Oat hay	Barley forage
Area (ha)	100	100	180	200	150
Yield (/ha)	15 Qt	15 Qt	1 Qt	40 t/ha	15 t/ha

Grain production of both oat and barley is also an important activity for the farm, each of them occupying an area of 100 ha. These crops are grazed in spring and harvested for grain at maturity, which appears to be a common practice in Tunisia in order to meet the early spring feed deficit in integrated crop–livestock production systems as reported by Keles *et al*. (2013). Kelman and Dove (2009) reported greater economic returns for dual-purpose wheat and oat crops compared with a grain-only option, particularly in dry seasons. The use of grazed cereal crops as a basic tool for reducing grazing pressure on rangeland has also been recommended for the Mediterranean basin (Tolu *et al.,* 2012). In order to reduce the gap of conventional forage production in the farm, about 42% of the total area was designed for shrub plantation such as acacia, spineless cactus, *Medicago arborea*, atriplex, etc. These shrub species are expected to cover nutritional requirements of sheep and goats at critical periods of the year (Table 4), together with grazing on harvest residues of hay or grains of cereals in spring and summer, respectively. Despite the diversity of feeding resources, there is increase in using concentrates, which represents a economic burden since its components, (maize, soybean and barley), are not local products and should be imported yearly.

Table 4. Forage calendar followed in the farm of Saouaf

Items	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Mai	Jun	Jly	Aug
Spineless cactus												
Atriplex												
Acacia												
Med. arborea												
Medique												
Green barley												
Hay residues												
cereal residues												
Hay												

2. Mating management

In farm Saouaf, males and females are entering reproduction at 18th months of age and retire at 6-7 years. Mating is organized during Spring (15 May-15 July) to line up maximum feed requirements with the annual peak of range production, so lambing occurs in the autumn (October-December). According to their body condition score males and females receive an energy supplement (flushing) consisting of 400-500 g of concentrate/barley, one or two months before mating and dur-

ing the whole mating season. Males generally receive oat grains in order to enhance their reproductive capacities. Therefore, based on the forage calendar (Table 3), it appears that nutritional requirements of animals are covered in that period. Likewise, one month before lambing (August), females receive concentrate at about 400-500 g/d as supplement to cover their energy requirements. Even though, fertility, fecundity and prolificacy rates (Table 5) were considered low, particularly for fat tailed breed, and did not correspond to the norms (fertility < 90%); however mortality of lambs mainly during the 1st day after lambing is high (>5%). It is pertinent to mention that all reproduction parameters were calculated including both breeds (fat tailed and thin tailed). Herein one should bear in mind that normally for the fat tailed breed during mating, assistance of the shepherd is indispensable in order to lift the female tail and assist the coitus for the male. However, shepherds for the five flocks of the farm are not competent due to the lack of experience and technicality. Moreover contracted shepherds are too old and young people are not interested as there is no juridical text that ensures their rights. Generally in Tunisia shepherds are not paid in money, but they receive a percentage (10%) on the weaned lambs production. Another issue is that the size of flock is considered too high (>200 heads) for an old shepherd, thus he cannot control all the flock at the same time. On the other hand and in order to increase the size of its own flock (10% of weaned lambs) and its profitability, shepherd buy other weaned lambs from non controlled flocks that could introduce a disease in the original flock. This practice could partly justify the high mortality for both young and adult animals (Table 5) that exceed the norms (>5%). The high mortality of lambs could be due also to the fact that lambing occurs in short period (October-December) and shepherd who maintains large flock cannot control the lambings at the same time and often the lambs die in the first days post lambing, due to mainly the lack of colostrum consumption. Birth weight of lambs is ranging between 3.2 and 3.5 kg, depending on the litter size and sex. Lambs receive an energy supplement at one month of age (100 g/d) till end February (300g/d) and are generally weaned at 6 month age (20 kg liveweight on average). Average weight productivity under these conditions is ranging at about 15.5 and 16.5 kg lamb/ewe. This is considered low and attributed to high mortality rate and low fertility. During the whole period of study ADG10-30 averaged between 270-280 g/d and ADG 30-70 between 200-250 g/d. These were in accordance to the growth performance of local breeds under semi-arid conditions (OEP, 2017). In order to improve reproduction parameters, two tools were adopted by OEP. The 1st consists of the use of artificial insemination that was applied lately (2016) for 182 fat tailed breed females and resulted in 54% lambing ewes and 126% prolificacy rate. The 2nd consists of the creation of a rams selection center that aims to distribute the better males for mating purposes. Actually the number of selected males is continuously increasing, being 192 in 2011 and 456 in 2016.

Table 5. Reproduction performance parameters (%) of sheep flocks in Saouaf farm (different breeds are included) during the six consecutive years (2011/2012 – 2016/2017)

Items (%)	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Fertility	79.9	83.2	87.0	86.1	82.0	77.3
Fecundity	83.4	86.6	103.8	93.9	95.1	89.0
Prolificacy	104.4	104.1	119.4	109.0	115.9	115.1
Lamb mortality	6.4	3.2	4.8	3.1	3.3	5.7
Adult mortality	9.1	6.7	5.6	7.2	3.7	8.9
Productivity	78.1	83.9	98.8	91.0	92.0	83.9

IV – Conclusions

Results of this present study revealed that, although nutritional requirements of the animals seem to be covered at different critical periods of the year, reproduction performance is considered poor. This should be due to, mainly, the lack of experience of shepherds. Different strategies were followed by OEP in order to enhance productivity of the sheep. Others strategies should be followed for the sustainability of livestock production under semi-arid conditions.

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Using eye tracking as an aid to pre-test choice experiments: an application to an online DCE on small ruminants' meat

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Abstract. The decrease in small ruminant's meat consumption in Europe during the last decades has been accentuated by consumers perception of small ruminant's meat as a traditional product, difficult to cook and with high prices. Additionally, the wide range of products and labels in the market, has forced consumer to rely on larger set of products' characteristics. However, given the limited capacity of the brain, not all this information can be processed. Our main objective is to understand which attributes consumers are interested in when selecting lamb/sheep meat. Through a Discrete Choice Experiment (DCE) using eye-tracking, we compared the stated preferences of the respondents in the DCE, the self-reported statements on non-attendance and their visual attention to each attribute and levels. We estimated a multinomial logit model (MNL) in R, that was used to design a final DCE. The data was collected in seven European countries (Finland, France, Greece, Italy, Spain, Turkey and United Kingdom) and analysed through MNL. Results show differences between the preferred attributes in each country. Only the price attribute was significant for all countries. We also found differences between the respondents self-reported statements and their visual attention.

Keywords. DCE – Eye tracking – Small ruminants' meat – MNL – Labels.

Utilisation de l'oculométrie comme outil d'essai préliminaire d'une enquête de choice experiment: application à une enquête en ligne sur la viande de petits ruminants

Résumé. *La diminution de la consommation de viande de petit ruminant en Europe au cours des dernières décennies a été accentuée par la perception par les consommateurs de la viande de petit ruminant en tant que produit traditionnel, difficile à cuisiner et à prix élevé. En outre, la vaste gamme de produits et d'étiquettes sur le marché a obligé les consommateurs à s'appuyer sur un ensemble plus large de caractéristiques. Cependant, compte tenu de la capacité limitée du cerveau, toutes ces informations ne peuvent pas être traitées. Notre objectif principal est de comprendre les attributs qui intéressent les consommateurs lors de la sélection de la viande d'agneau/de brebis. Dans le cadre d'une expérience de choix discret (DCE) utilisant l'oculométrie (eye-tracking), nous avons comparé les préférences déclarées des répondants dans DCE, les déclarations autodéclarées sur la non-participation et leur attention visuelle à chaque attribut et niveau. Nous avons estimé un modèle logit multinomial (MNL) en R, utilisé pour concevoir un DCE final. Les données ont été collectées dans sept pays européens (Finlande, France, Grèce, Italie, Espagne, Turquie et Royaume-Uni) et analysées via une MNL. Les résultats montrent des différences entre les attributs préférés dans chaque pays. Seul l'attribut de prix était significatif pour tous les pays. Nous avons également constaté des différences entre les préférences exprimées par les répondants et leur attention visuelle.*

Mots-clés. *DCE – Eye tracking – Viande de petits ruminants – MNL – Etiquettes.*

I – Introduction

In the last decades, small ruminant's meat consumption in Europe has stagnated (European Commission, 2018). The perception of a traditional product with high prices, difficult to cook and with specific taste, has driven consumers away. Especially young consumers, as the meat often is sold in family-sized portions; but, when new products were introduced for them, the sales increased (Pol-

icy Department: Structural and Cohesion Policies – European Parliment, 2008), which shows the potential of a market that has been underdeveloped.

Consumers need to rely on a large set of products' characteristics and not all this information can be processed, given the limited time and capacity of the brain (Ares *et al*., 2014). Previous studies suggest that to simplify complex decisions, respondents may follow some decision rules or "heuristics", which result in non-attendance to certain attributes (Orquin and Mueller Loose, 2013). This has become a problem in discreet choice experiments (DCE), as if respondents do not attend to all the attributes, this could lead to biased results (Caputo *et al*., 2016).

Our main objective is to understand which attributes consumers are interested in when selecting lamb/sheep meat. Through a DCE using eye-tracking, we compared the stated preferences of the respondents in the DCE, the self-reported statements on non-attendance (Scarpa *et al*., 2013) and their visual attention to each attribute and levels (Erdem *et al*., 2015). We used the results to create a DCE in wider scale, which included only the key attributes for the consumers

II – Materials and methods

1. Pilot study design

We designed a labelled DCE. Each choice task contained a non-choice alternative and four types of meat in specific cuts: lamb leg, lamb chops, goat chops, T-bone steak. Based on the results from previous studies and focus groups, we selected eleven credence attributes for the design of a pilot choice experiment: price, halal label, origin, Protected Geographical Indication label – PGI, animal feeding, carbon footprint label, organic label, fat content, protein content, cholesterol content label and preparation (normal or ready to cook). Attributes varied between two and three levels. Prices were set fix and adjusted in +/-30% by each type of meat and cut.

We developed a hypothetical DCE, as some of the labels and attributes are not currently present in all the target markets included in the study. Each respondent was presented with six choice tasks. We designed the DCE using a D-efficient approach in the Ngene software. All choice sets and alternatives were randomly presented to avoid bias. For the pilot study, we collected a total of 138 choices. The panel data was analysed using multinomial logit code in R and used for the development of a final DCE that included only the key attributes.

We collected the data for the pilot study in Ancona (Italy), in October 2018. All participants were meat consumers and ate lamb at least once in the last year. While the respondents were answering the choice experiment, their visual attention was recorded using a contact-free eye-tracking device. As in previous works (Balcombe *et al*., 2015), participants viewed each choice set as long as they need it and then selected one of the alternatives of the choice. We analysed the eye-tracking data by defining areas of interest (AOIs) on the products and heat maps. After performing a qualitative analysis on the results, some attributes were dropped for the final DCE.

2. Final DCE design and data collection

Based on the pilot study results, we designed a label and hypothetical DCE, using an efficient design. Each choice task included a non-choice alternative and the same four types of meat used in the pilot. We develop 24 choice tasks in 2 blocks. The product attributes were adapted according to the results from the pilot study. Between mid-March to mid-May 2019, we collected more than 400 responses from each of the following countries: Finland, France, Greece, Italy, Spain, Turkey and UK, equivalent to 34,392 choices. We analysed the data using MNL in R.

III – Results and discussion

1. Pilot study results

The MNL estimation based on the DCE and the eye-tracking data resulted in substantially similar results. Results show that price is an important attribute for consumers and, as expected, has a significantly negative coefficient. The organic label gets also significant attention from consumers and had a significant positive effect on the choices of consumers. These results match with previous literature (Apostolidis and McLeay, 2016; Zanoli *et al.*, 2013) and can be observed in the heat maps on Fig 1.

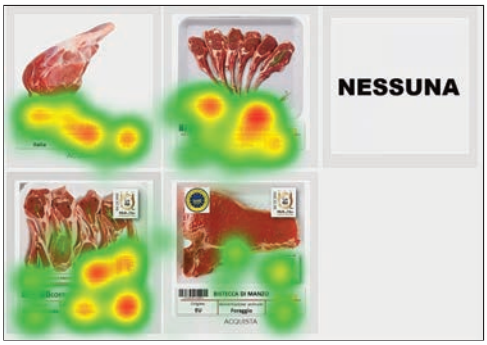

Fig. 1. Heat map from an eye-tracking respondent.

However, we found some differences among DCE, eye-tracking results and the consumers' self-reports on non-attendance. The protein label gained many consumers' visual attention (Fig.1); in the DCE model estimates the corresponding coefficient was significant but negative. Nevertheless, most respondents declared not considering it when making their choice. The same happened to the preparation format, which was also reported as non-attended, but it was found significant albeit negative in the DCE estimates.

The national origin and the PGI label had a significant positive effect on the choices of consumers and got some visual attention during the selection process. However, respondents declared to not pay attention to the origin of the meat when selecting their choice. Given the pilot study results, the attributes animal feeding and cholesterol content were removed from the final DCE model.

2. International DCE results

Results vary between countries, as it can be seen in Table 1.

Beef is usually preferred over lamb cuts, except for lamb chops in ES and TR. Price is significant and has a negative coefficient in all countries. National origin and organic label have positive coefficients and are the most important attributes in FI, FR, GR and IT. National origin is also important in ES and TR. In FI, FR, IT and ES, EU origin has also a positive coefficient, although always smaller than the national one. Only in TR halal is perceived as an important attribute with a positive coefficient. For UK consumers, organic was the most important attribute with a positive coefficient. IGP label and Carbon footprint have a positive coefficient for GR, ES and TR; while the high protein content label has a negative coefficient and is significant only in FI and UK. The ready to eat preparation is significant in FI, GR and SP. In FI, the ready to eat preparation is appreciated by consumers, while in GR and ES it has a negative coefficient. Lower fat content is only significant in IT and has a small coefficient.

Table 1. MNL estimation results for the final DCE for Finland, France, Greece, Italy, Spain, Turkey and UK

	Finland		France		Greece		Italy		Spain		Turkey		UK	
Final LL	-7308.62		-7523.24		-7469.13		-7450.41		-7612.75		-7158.37		-7514.05	
Adjust Rho sqr	0.082		0.057		0.031		0.073		0.053		0.050		0.059	
Estimates	Coeff.	Std.error	Coeff.	Std.error	Coeff.	Std.error	Coeff.	Std.error	Coeff.	Std.error	Coeff.	Std.error	Coeff.	Std.error
Lamb leg cte.	-0.568	0.044	-0.374	0.066	-0.703	0.064	-0.640	0.046	-0.192	0.043	-0.509	0.052	-0.335	0.068
Lamb chops cte.	-0.214	0.045	-0.108	0.046	-0.388	0.053	-0.044*	0.039	0.519	0.045	0.131	0.041	-0.117*	0.064
Goat chops cte.	-0.729	0.057	-1.048	0.065	-0.670	0.058	-0.786	0.054	-0.054*	0.067	-0.726	0.067	-1.292	0.083
Beef T-bone cte.	0.000	NA	0.000	NA	0.000	NA	0.000	NA	0.000	NA	0.000	NA	0.000	NA
None cte.	-1.427	0.091	-0.738	0.110	-0.651	0.111	-1.552	0.094	-1.048	0.085	-0.955	0.107	-1.496	0.123
Price	-0.168	0.007	-0.092	0.006	-0.134	0.013	-0.166	0.008	-0.114	0.007	-0.020	0.002	-0.165	0.010
Halal label	-0.097	0.034	-0.165	0.033	0.044*	0.033	-0.058*	0.031	-0.168	0.032	0.363	0.032	-0.096	0.033
National origin	0.552	0.051	0.511	0.053	0.584	0.052	0.592	0.050	0.418	0.051	0.412	0.046	0.096*	0.050
EU origin	0.159	0.059	0.212	0.054	0.070*	0.056	0.114	0.052	0.185	0.051	0.074*	0.058	-0.017*	0.051
IGP label	0.062*	0.059	0.111	0.038	0.234	0.037	0.177	0.037	0.100	0.037	0.229	0.056	0.092	0.039
Carbon footprint	0.090	0.034	0.062*	0.033	0.118	0.033	0.037*	0.031	0.080	0.032	0.140	0.032	0.025*	0.033
Organic label	0.224	0.038	0.327	0.038	0.267	0.036	0.231	0.035	0.066*	0.035	0.201	0.036	0.177	0.037
Lower fat content	0.057*	0.038	0.070*	0.036	0.043*	0.037	0.076	0.034	0.035*	0.035	0.016*	0.036	0.034*	0.036
High protein	-0.071	0.036	-0.017*	0.035	-0.030*	0.034	-0.012*	0.033	0.005*	0.033	-0.063*	0.033	-0.085	0.034
Ready to eat	0.089	0.034	-0.048*	0.034	-0.138	0.033	-0.017*	0.031	-0.150	0.032	0.003*	0.032	-0.012*	0.034

*The coeffient is not significant at significant level of 0.05

IV – Conclusions

Our results present an alternative way for the selection/reduction of attributes and their levels in the development of future DCE. Accordingly, organic labels, price and origin continue being the way in which products signal their quality and are a must for the development of DCE in lamb meat. Other attributes as PGI, halal label and carbon footprint might vary between countries and should be taken into consideration depending on the market under study.

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Revisiting crop and livestock integration in sheep and goat systems of Morocco: new insights

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Abstract. Mixed farming with crops and livestock, particularly cereals associated with sheep rearing has been and still is the predominant farming system in Morocco. Because of the high diversity of topography, soils, climate, the extent of arable, rangelands, crop and livestock integration in sheep and goat systems takes a variety of forms. The integration depends on cultivated crops on-farm, available feed sources, breeds, and production objectives. Most studies on Moroccan sheep and goat systems adopt technicist approaches. The aim of this paper is to revisit the main sheep and goat production systems. It is based on specialised studies and field work on sheep and goats in the Middle-Atlas, Azilal and the plains of Settat and Khouribga provinces. The analysis focuses on the pastoral system of the eastern steppes as an example of the occurring shifts in sheep production. It is argued that the use of typologies hides the evolutionary processes underlying the production systems and the extent of diversity and interaction within systems. For a better understanding of crop-livestock integration, multi-disciplinary approaches are necessary.

Keywords. *Morocco – Sheep – Goats – Mixed farms – Integration.*

L'intégration cultures/élevage revisitée à travers l'étude des systèmes ovins et caprins au Maroc: nouveaux éclairages

Résumé*. L'agriculture mixte (cultures et élevage), en particulier les céréales associées à l'élevage ovin, a été et reste le système d'exploitation prédominant au Maroc. En raison de la grande diversité de la topographie, des sols, des conditions climatiques, de l'étendue des terres arables, des parcours et des terres marginales, l'intégration des cultures/élevages (ovins et caprins) revêt de nombreuses formes. D'autres facteurs peuvent définir la nature de l'intégration notamment les cultures pratiquées, les sources d'alimentation supplémentaires disponibles, les races et les objectifs de production. La plupart des études sur les systèmes ovins et caprins marocains adopte des approches technicistes. Dans ce papier, les systèmes de production ovins sont revisités. Le travail est basé sur une revue de la littérature et des travaux antérieurs sur le terrain dans le Moyen Atlas, les provinces d'Azilal, de Settat et de Khouribga. L'analyse se concentre sur le système pastoral des steppes orientales en tant qu'exemple des changements survenus dans la production ovine. Il est avancé que l'utilisation de typologies cache les processus évolutifs sous-jacents aux systèmes de production et l'étendue de la diversité et de l'interaction au sein des systèmes. Pour une meilleure compréhension de l'intégration cultures – élevages, des approches multidisciplinaires sont nécessaires.*

Mots-clés. *Maroc – Ovin – Caprin – Exploitations mixtes – Intégration.*

I – Introduction

According to the 2014 census, the Moroccan population counts 33.8 million with the rural people representing less than 40% (HCP, 2014). Despite the continuous urbanization, agriculture still occupies an important place in the economy with sheep and goats contribution to the country's GDP estimated between 1.5% and 2% (Boujenane, 2005). In the last three decades, agriculture and livestock husbandry have witnessed an increased intensification with greater interactions between crops and livestock. This resulted in the transformation of extensive pastoralism to semi-intensive mixed farming. The latter is seen as the most efficient and sustainable means of increasing food production and coping with risks. In fact, it is documented that diversification of subsistence agriculture and

livestock activities is a way to cope with climatic risk. Most arable lands and rangelands are located in areas receiving less than 400 mm of rainfall, where cereals and small ruminants mainly sheep are integral components. The aim of this paper is to revisit the main sheep and goat systems in Morocco. The paper builds on specialized works on production systems, namely Guessous *et al*. (1989); Boujenane (2005); Boulanouar (2006); Boulanouar and Benlekhal (2006). The authors also draw from their observations and fieldwork on sheep and goats in the Middle Atlas, Azilal, Chaouia and Khouribga regions (Chriyaa *et al*., 2011; El Amiri, 2006; El Amiri *et al*., 2007; Sibaoueih *et al*., 2019).

II – Predominant forms of crop/livestock integration and changes

The first comprehensive work on sheep in Morocco classified production systems according to the type of feed resources, namely the pastoral, the agro-pastoral and the oasis system (Guessous *et al*., 1989). Later, the research program on small ruminants at the National Institute of Agricultural Research, in collaboration with the German Technical Cooperation, established a typology of sheep production systems in 1992 (Boulanouar, 2006). The four systems identified were the pastoral, the agro-pastoral, the agro-sylvo-pastoral and the oasis systems. For the classification of Guessous *et al*. (1989), the pastoral system was defined based on the predominance of range forages contributing over 50% of total feed resources with herds spending from 8 months to all year around on rangelands. Geographically, the pastoral system is characteristic of the Middle-Atlas, the high plateau and the Moulouya basin. Boulanouar and Benlekhal (2006) reported that the pastoral system is dominant in mountains with forest and non-forest rangelands, the arid steppes where agriculture is uncertain, the High Plateaux of Eastern Morocco, the southern side of the High Atlas, and Chaouia and Rhamna regions. The agro-pastoral system prevails in areas producing cereals and legumes, namely Gharb, Doukkala, Chaouia, Abda, Taounate, Khemisset (Guessous at al., 1989). Sheep flocks rely significantly on on-farm production including cereal and legume grains as well as their by-products. When necessary the market provides a variety of feed products. The oasis system is confined to oasis particularly in the Drâa-Tafilalet region and Figuig oasis. Cereal by-products, alfalfa and date by-products are the major feeds for sheep consisting of small size flocks of all year around penned and highly prolific D'man breed.

Over the last three decades, Morocco has experienced complex processes of change including all spheres of the economy, the society and the natural environment. Sheep production systems have had their part of transformation and change. While the concepts of agro-pastoral and oasis systems continue to be relevant today, the concept of pastoral sheep production is increasingly losing its empirical grounds. As indicated in Table 1, cereals and cereals by– products, crop residues of all kinds are increasingly generalized as feeding stuffs across the country including the conventionally defined as pastoral areas, namely the eastern steppes and the Middle-Atlas. This implies that sheep production is relying less on range pastures and more on crops and crop by-products whether from on-farm production or acquired through the market. In the eastern steppes of Morocco, cropping activities were marginal particularly among the nomadic herders. With the settlement of most nomads, growing cereals and forage crops are becoming of paramount importance. According to the 2014 population census, the nomadic population in Morocco stands at 25,274 people compared with 68,540 in 2004. This 63% decline over a decade is a clear indicator about the direction of change in sheep production in the future. At the regional level, Drâa-Tafilalet accounted for 61%, the Guelmim-Oued Noun counted for 21% and the region of the Oriental recorded 2% of all nomads (HCP, 2016). The eastern steppes are traditionally considered the center of pastoral nomadism.

With respect to goats, the contribution of range feeding is rather substantial, varying from 75% to 97% of annual animal requirements, depending on climatic conditions of the year and/or regions (Boujenane, 2005). In the north of the country, Chentouf (2018) reported that pastoral resources covered about 96% of the animal needs in the extensive goat meat production system. The meat and milk system relies on both pastoral resources (from 49 to 78% of total needs) and other feed resources from the farm or the market (Chentouf, 2018).

Table 1. Sheep systems in Morocco, main characteristics, breeds and feed resources

Production system	Administrative provinces	Predominant breed in numbers	Major feed resources
Agro-pastoral in the central plains	– Settat – El Kelâa des Saghna – Rhamna – Beni Mellal	Sardi (2.1 million heads) represents 13% of Morocco's total	Barley grain, straw, weedy fallow, stubble, crop residues, cultivated forages
Agro-pastoral in the eastern steppes-Figuig	– Taourirt – Guercif – Jerada	Beni-Guil (1.9 million heads) represents 12.5% of Morocco's total	Range pastures, barley grain, cereal straw and stubble, wheat bran, crop residues
Agro-sylvo-pastoral in the Middle-Atlas	– Ifrane – Boulemane – El Hajeb – Sefrou	Timahdit (1.5 million heads) represents 10% of Morocco's total	Forest / highland pastures, cereal straw, stubble, weedy fallow, crop residues
Agro-pastoral of the Atlantic (irrigated and ainfed areas)	– Kénitra – El Jadia – Safi	Local sheep populations	Cereal straw, fallow, stubble, alfalfa, sugar beet by-products, bran, crop residues
Agro-pastoral	– Khouribga (Oued Zem-Boujâd) – Beni-Mellal (Tadla)	Boujaâd (230 000 heads)	Cereal straw, fallow, stubble –alfalfa, sugar beet by–products,other crop residues
Argan forest-farming system	– Essaouira – Taroudant – Agadir Ida–Ou-Tanan	Local sheep populations	Argan sub-products, cereal by products, crop residues
Oases	– Errachidia – Ouarzazate –Zagora	D'man (260 000 heads)	Alfalfa (fresh-hay), dates by-products, cereal by-products, crop residues

Source: compiled by authors.

III – Main constraints

Natural diversity is a major characteristic of Morocco displayed in the presence of mountain ranges in the Rif and Atlas, central plains, steppes and Saharan environments. This results in climatic zones varying from warm, dry in summer and mild in winter to hot desert. Average annual precipitations vary from over 1,200 mm in the North with two seasonal peaks in winter and spring, to below 100 mm in the South. Across the country, crop and livestock activities are climate dependant. The availability of feed resources and animal species are closely associated with rainfall patterns. The analysis of the evolution of sheep and goat population over the last 50 years reveals the close relation between the extent of fluctuations in stock numbers and drought episodes in Morocco. In 1982, Morocco lost 35% of its national sheep flock and 25% of the goat flock because of the drought.

As highlighted in the literature, local sheep breeds are known by their rusticity, diversity and adaptation to prevailing environmental conditions (Boujenane, 2005; Boulanouar and Benlekhal, 2006). Table 1 indicates that these breeds are integral parts of particular climate, environmental and production zones. Herders and farmers select not only the animal breeds that are likely to withstand the prevailing environmental conditions but they also grow most adapted crops to prevailing conditions.

IV – Prospects

Between the 1982 and the 2014 population censuses, the rate of urbanisation in Morocco moved from 42.7% to 60.3%. This means that urban consumers represent the largest share of the current and future demand for sheep and goat products, grains, vegetables and fruits. The tendency to respond to market driven products for an increasing urban population needs to be considered in apprehending the occurring shifts in sheep and goat production systems. Pastoral activities are increasingly associated with cropping activities through shifts in land use, irrigation and modernisation of farming practices. For example, cultivation of forages covered 128,000 hectares against 441,718 hectares in 2005. The future is likely to unravel a greater diversification of feed sources, less reliance on rangelands and more use of crops by products and concentrates, and more integration in the market.

A better understanding of the directions of these changes requires the availability of national agricultural statistics. Since independence in 1956, Morocco conducted two general agricultural censuses, the first one in 1973 and the second in 1996. Since 2015, the ministry of agriculture has been talking about the National Agricultural Register. Until today, there are not any information accessible to the public. Besides, it is not clear whether or not that the initiative is an alternative to the general agricultural census. Without longitudinal updated data of wide coverage, it is very difficult to apprehend the evolving links between land use, livestock numbers and distribution.

V – Conclusion

In Morocco, farmers and herders are diversifying their activities as coping strategies to face unreliable climate and market requirements. Mixed farms allow more flexibility and more resilience in face of risks. The use of typologies hides the evolutionary processes underlying the production systems and the extent of diversity and interaction within systems. For a better understanding of crop-livestock integration, multi-disciplinary approaches are necessary.

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The value chain of Siroua Moroccan woolly sheep

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Abstract. With a total of 263,000 heads, the Siroua woolly sheep is a breed that encompasses two variants, the "Blanche de Montagne" and "Noire de Siroua", and has an important economic and social role for a large number of families in the High and the Anti-Atlas Mountains in Morocco. Due to its small size, this breed has received very little attention as one of Moroccan standard breeds. Recently, the Siroua woolly sheep is attracting increasing attention of the Ministry of agriculture, NGOs, and researchers. In the present study, the value chain of this breed is explored trough the description of the breed, its production (meat and wool), the carpet production and the marketing. Analyses on meat and wool productions were based on surveys targeting stakeholders, technicians, herders, shepherds and carpet cooperatives. The results showed that for a long time the breed was appreciated mainly for its high-quality wool production characterized by long fibre, which makes it unique in Morocco. For example, the pricy and the famous "carpets of Taznakhte" are made of Siroua's wool. This typical carpet was facing problems, related to market competition, that have recently been partially resolved thanks to the efforts of some cooperatives. Regarding meat production, it is worth noting that the small size of the Siroua sheep limits its competitiveness with other Moroccan breeds. Based on the local knowledge, the breed has a typical meat produced on a large list of aromatic plant pastures. Currently, new concepts such as, but not limited to, label, diversity, and conservation revive the breed and boost studies towards meat quality. Globally, through giving particular attention to herders and shepherds the two variants of Siroua breed offer significant opportunities for the production of both meat and wool.

Keywords. Blanche de montagne – Noire de Siroua – Wool – Taznakhte's carpet – Meat.

La chaine de valeur de la race ovine marocaine lainière de Siroua

Résumé. *Avec un total de 263 000 têtes, la race lainière Siroua, avec ses deux variantes "Blanche de montagne" et "Noire de Siroua", joue un rôle économique et social important pour un grand nombre de familles du Haut et de l'Anti-Atlas du Maroc. En raison de sa petite taille, cette race a été pour longtemps ignorée des listes des races standards marocaines. Récemment, elle attire de plus en plus l'attention du ministère, des ONGs et des chercheurs. Dans la présente étude, la chaîne de valeur de cette race est explorée à travers la description de la race, sa production (viande et laine), la production de tapis et la commercialisation. L'analyse des productions de laine et de viande a été basée sur une enquête ciblant les décideurs, les techniciens, les éleveurs, les bergers et les coopératives de tapis. Les résultats ont montré que la race a longtemps été considérée principalement pour sa production de laine. Il est connu pour produire une laine de meilleure qualité présentant surtout une longue mèche l'identifiant comme unique au Maroc. Le prix de la laine Siroua est élevé et elle est à la base du fameux "tapis de Taznakhte". Ce dernier a confronté des problèmes, de marché et de concurrence, qui ont été partiellement surmontés grâce aux efforts de certaines coopératives. Concernant la production de viande, la petite taille de la race Siroua l'empêche d'être compétitive par rapports autres races marocaines. Sur la base des connaissances locales, la race produit une viande typique basée sur une grande liste de plantes pâturées. Aujourd'hui, de nouveaux concepts (label, diversité, conservation) font revivre la race et poussent les études vers la qualité de la viande, entre autres. Pour conclure, la race Siroua avec ses deux variantes doit être considérée pour la production de viande et de laine avec une attention particulière aux éleveurs et aux bergers.*

Mots-clés. *Blanche de montagne – Noire de Siroua – Laine – Tapis de Taznakhte – Viande.*

I – Introduction

The Siroua has been described as a Moroccan sheep breed that includes two variants the white (*Blanche de Montagne*) and the black (*Noire de Siroua* about 50,000 heads) variants (Ezzahiri, 1981a). Due to its small size (weight < 40 kg) it has long been ignored in Moroccan sheep programs. This is because, as compared to other mountains in Morocco, the Siroua Mountain attracted less attention for such studies which severely affected investigations on the sheep (Birouk, 2009). To increase productivity, the Siroua breed was crossed with Timahdit rams (Ezzahiri, 1981b). At that time, enhancing productivity was dominating the livestock strategies. From 2006, the Siroua breed regained its place among other Moroccan sheep thanks to many national and international initiatives. Recently in 2010 and 2015, the white and black variants were registered in the official book of ANOC (National Association of sheep and goat) respectively. Breed production and growth performances have been characterized mainly for its exceptional wool quality, the Siroua breed is one of the pillars of artisanal products (carpets of Taznakhte or Ait Ouaouzguit). Additionally, both black and white variants are known for their meat with special good taste due primarily to natural grazing. Nonetheless, data on the Siroua breed remains limited and confined to some technical reference documents. In the present study, the value chain of this breed is explored.

II – Materials and methods

The study was carried out in different sites from Ouarzazate-Province in the Southeastern Morocco (Iznaguen; Askaoun; Taznaght, Ouarzazate and Sidi Hsain). Analyses of wool and meat productions were based on surveys targeting stakeholders in regional departments of the ministry of agriculture (ORMVAO, ONSSA), technicians of the ANOC, herders, shepherds and carpet cooperatives. Two workshops were organized and individual surveys were achieved to collect the data used in the analyses. The analysis of literature review, the survey tools, were using a checklist on production of meat and wool, marketing and consumption of Siroua breed. More precisely, a structured questionnaire focused on the main aspects of small ruminant's production, husbandry practices, processing, marketing, consumption and products perception was prepared. A total of 40 households owning flocks were randomly selected among ANOC and non ANOC farmers for survey.

III – From Siroua sheep to Taznakhte carpets

1. Siroua sheep characteristics

Siroua sheep constitutes with Saghro sheep the two main sheep populations bred in a rangeland-based system in the studied area, with a total census of 600,000 heads (Ezzahiri, 1983). The Siroua sheep is highly adapted to its harsh environment. It is a small sized animal with a body length varying from 60 to 70 cm and a rump height varying from 55 to 65 cm. The body weight is 25-40 kg for rams and 20-30 kg for ewes (Ezzahiri, 1981a). Despite improvement and selection programs carried out by ANOC, the body measurements recorded recently by Jannoune and Fagouri (2011) and Kandoussi (2017) did not seem to be different from those previously reported by Ezzahiri (1981a). Interviews with different stakeholders confirmed the social and economic of Siroua sheep roles. In fact, the breed contributes largely to farm's income through the sale of various animal parts and byproducts (manure, wool, carpets, etc.).

2. Siroua sheep wool

The Siroua wool is either uniformly white or uniformly black or a mixture, with dense fleece covering the head and the whole body allowing good protection outdoors in both winter and summer. Key wool characteristics include: fibre diameter, fibre diameter coefficient of variation, comfort factor, fibre cur-

vature, spinning fineness, staple length, staple strength, and clean fleece yield. All these characteristics are not yet established for Siroua sheep wool until now. The totally black or white wool represents about 25% each from the total production while the mixture represents the remaining 50%. The greasy fleece weight varies from 1.5 to 4 kg (Ezzahiri, 1981a; Jannoune et Fagouri, 2011). The length of its fibre varies with body parts. It reaches 15 cm at the back level, 22 cm at the thighs and pelvis and 28 cm around the neck (Jannoune and Fagouri, 2012). According to the same authors, it can also be sex dependent. The length of white wool is about 19.69±1.93 cm in males and 11.93±2.21 cm in females. Ezzahiri (1981a) highlighted that Siroua wool price overcome all Moroccan sheep wool about 30%. Black wool is especially more expensive as it is preferred to white wool because it offers more possibilities for greater colour combinations. Presently, Black greasy fleece costs 25 to 35 DH/kg, while the white cots only 10 to 15 DH/kg, and becomes as cheaper as 5-7.5 DH when it is a mixture. Wool could be classified as "alive" or "death". The former, is collected after shaving live animals or from the body parts that are exposed to the sun. The latter is collected from slaughtered animals or from the down body that is not exposed to the sun. "Death wool" and down body wool do not retain well the dye and are not appreciated by weavers. Based on our surveys, the farmers declared that wool colour changes according to latitude. In highlands wool is brighter. The wool of Siroua is used to produce many artisanal items, especially the well-known Taznakhte carpet.

3. The Taznakhte carpet

Taznakhte or Ouazguite carpet is very famous in Morocco and well-known among tourists who have visited and subsequently promoted significantly the image of the region at the international level. The Taznakhte carpet has been known historically since late 1800s and early 1900s. During this period, attempts were made to modernize its patterns, colour, etc. Currently, Taznakhte carpet has a very high density of nodes showing about 500,000 per square meter achieved in 9 months. For generations, women have been making carpets with characteristics and patterns that are specific to the region. In bright colours and different sizes, the Taznakhte carpets are the models of paintings made by skilful hands. It is full of signs and geometric shapes. There are, for example, squares, triangles, circles and symbols of *Tifinagh* that express the Amazigh identity. Animal figures, birds, camels and lamps can also be a part of Taznakhte carpet. The variety of signs is linked to everyday women's life. When talking about their carpets, all of the surveyed persons used expressions as if they were talking about humans. They used expressions like "*Tapis heureux*" or "*Tapis triste*" implying that this is a real artwork. Choice of colors is of great interest and mainly based on warm ones such as orange, yellow and red. Chemical dyes give opportunities to multiply colours. However, women still use local methods to dye wool. Flowers, leaves, fruits, sun-dried insects are used. Besides, madder roots cochineals, purple, poppy, henna, walnut, pomegranate and apple bark, alone or in mixture, allow performing a variety of colours. Tea, saffron, Daphne, petals of broom and mimosa allow to enrich shades of bright yellow and pastel. Ochre is used in dying carpets as well.

According to cooperatives survey, the carpet artwork is an ancestral activity, the mother and all other women members of the family hold this knowledge and transmit it to their daughters. Women are organized in groups to work together or alone with their daughters. Weaving skills is even one of the criteria that highlight the talents of a new wife at the regional level. Through carpet work women express their emotions and have a moment to escape housework.

IV – Siroua carpet market

Marketing is rarely attributed to the weavers. It is a task of men or cooperatives. Women who work from home delegate marketing to cooperatives. The carpet of Taznakhte suffers from imitations and deficient marketing. A good quality carpet of 1.5x2.5 m requires 2-month work done by three women can be sold at 2,500 DH. A carpet of 4 m^2 for example requires 3-month work; it can be sold at about

1,500 DH if ordered while the price will drastically be reduced to 300-500 DH when sold in a local market. In general, the price depends on the quality of wool, patterns, and softness. Currently, four women's cooperatives are in contract with the Wool Collection Center managed by ANOC. Some weavers benefit from capacity building on designs, and how to deal with crude material from grassy wool to a carpet. They also learned how to valorize and diversify their products. About 22,000 women in Ouarzazate province are working on carpets. Today, carpet weaving in Taznakhte has become a means of social development. It is especially a source of complementary income for families. Besides, the yearly Taznakhte carpet festival is opening other market doors for this product.

V – Siroua breed meat

Based on their body weight (17-24 kg for ewes and 23 to 40 kg for rams), Siroua breed carcasses are very light. A carcass monitoring in Tazenakhte and Askaoune slaughterhouses revealed their light weight varying from 12 to 20 kg depending on age and fattening quality (Ezzahiri, 1981a). The surveyed persons indicated that meat quality is the consequence of feeding management based on grazing in good quality pastures in Ouarzazate province. According to Birouk (2009), the low altitudes of Siroua's mountains are dominated by white wormwood (*Artemisia herba alba*) and the slopes are mostly covered by red juniper (*Juniperus phoenicea*). On the high slopes (between 2,500 and 3,300 m altitude), the vegetation is of xerophytic type (*Erinacea anthyllis, Alyssum spinosum, Bupleurum spinosum, Astragalus ibrahimianus*) rich in species with high pastoral and ecological value (*Festuca rubra, Poa bulbosa, Nardus stricta*). Feeding on this wide range of plants contribute significantly to the Siroua sheep its typicity. However, despite its dietetic and other distinctive assets, the Siroua's meat still does not have its share in the meat market. Recently consumers from large cities in Morocco have been showing a greater interest for it. To overcome this hurdle, research might be geared toward getting deeper insights into the benefits of the Siroua's meat and subsequently establish a labeling system for this product to be more market competitive.

VI – Conclusions

The characteristics of both variants of the Siroua sheep suggest that this breed is reared for the production of both meat and wool. The profitability of Siroua rearing projects should be estimated based on its productivity in terms of these two main products. Further studies need to be undertaken to establish the "typicity" of meat. Laboratory tests need to be implemented to track down the origin of wool used in Taznakhte carpet. Healthy and well managed animals, produce good quality wool. However, the carpet value chain is not equitable towards farmers and shepherds. Carpet production activities need to be undertaken in the framework of more solidary value chain that benefits all actors for sustainable Siroua wool-made carpet production.

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Goat farming in Algerian steppe region: constraints and perspectives

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Abstract. This study aims to characterize the goat farming in steppe zone at M'sila region (Algeria) and to identify its main constraints. In Algeria, goats are distributed mainly in the mountains, the steppe and Saharan areas. The goat population in this agro-pastoral region is about 140000 goats of which 90000 females. A survey of 64 breeders confirmed extensive and mixed management with sheep. The price of goat meat has been in line with sheep's meat, which remains the most consumed meat in the study area. The market demand for goat meat is accentuated especially during the aid Al-Adha and Ramadhan as well as for the farmers' fresh money requirements. Goats are sold around 30000 Algerian dinars depending on age and weight. Otherwise, the price of goat milk, which is gaining interest, has tripled. Despite the attractive price of the goat milk, 67% of the breeders prefer it for to self-consumption. These farms are almost exclusively conducted by men (97%) of over 55 years old. Better organization of the goat sector could make it more profitable and play an important role in rural development.

Keyswords. Goat farming – Steppe zone – Meat – Milk – Constraints.

L'élevage caprin en région steppique algérienne: contraintes et perspectives

Résumé. *Cette étude a pour objectif de caractériser l'élevage caprin en zone steppique dans la région de M'sila et d'identifier ses principales contraintes. En Algérie, le cheptel caprin est réparti essentiellement dans les montagnes, les zones steppiques et les zones sahariennes. L'effectif caprin dans cette région agropastorale est d'environ 140000 têtes dont 90000 chèvres. Une enquête auprès de 64 éleveurs a confirmé la conduite en extensif et mixte avec les ovins. Le prix de la viande caprine s'est aligné avec celui de l'ovin qui reste la viande la plus consommée dans la région d'étude. La demande du marché en viande caprine s'accentue notamment lors de périodes de fêtes de l'aïd Al-adha et du ramadhan ainsi que lors de besoins en argent frais des éleveurs. Les chevreaux sont vendus environ 30000 dinars Algérien, selon leur âge et leur poids. Par ailleurs, le lait de chèvre connaît un regain d'intérêt et son prix a triplé. En dépit du prix attractif du lait de chèvre, 67 % des éleveurs enquêtés le destinent en priorité à l'autoconsommation. Ces élevages sont quasi exclusivement conduits par des hommes (97%) âgés de plus de 55 ans. Une meilleure organisation de la filière caprine pourrait la rendre plus rentable et jouer un rôle important dans le développement rural.*

Mots-clés. *Élevage caprin – Zone steppique – Viande – Lait – Contraintes.*

I – Introduction

Goat is known for its adaptation to very rough farming conditions. In Algeria, it is practiced in mountains in the north of the country, but most of the population is distributed in the steppe and sub-desert areas. It is conducted in extensive (Mouhous *et al*., 2015; Guermah *et al*., 2018). Goat farming is an important family activity in M'sila region. Technicity is transmitted from generation to generation. The goat population in Algeria is estimated at 5.129.838 in 2014 (DSA, 2016). Goat meat conveys the image of a biological product. It represents a source of animal protein but also income for rural

populations, especially in developing countries (Escareño *et al*., 2013). Goats are also bred for their desired fleece and skin which is used in particular for the manufacture of guerbas which are lightweight, insulating and easy to carry. They are widely used in the study area. The wilaya (district) of M'sila is part of the Hodna region. This region is located south of the highlands in central Algeria. It covers an area of 18.175 km^2 for an estimated population of 1 210 952 inhabitants (www.wilaya-msila.dz). More than 30% of the population is concentrated in three important cities: M'Sila, Bou-Saâda and Sidi Aissa. Its main purpose remains agro-pastoralism dependent on low and irregular rainfall. The south of the region receives less than 200mm/year. The north area receives more than 480 mm /year. The climate of the wilaya is of continental type subjected in part to the Saharan influences. It is dry and very hot in summer and very cold in winter. Rangelands and pastures occupy a very large area, 1029564 ha or 56.65% of the total agricultural area. The study of the potentialities of goat farms in this agro-pastoral region remains insufficient.The aim of this work is the characterisation of goat farming and determination of its main constraints in M'Sila region.

II – Materials and methods

In order to characterize the behavior of goat farms and to identify the main constraints, a questionnaire survey of 64 breeders was conducted. Questionnaires concerned firstly the social aspect of the farmer, his age, his level of education, and on the other hand livestock management, feeding mode, type of production. The choice of surveyed areas was made following interviews with veterinarians, butchers and especially the guidance of the agricultural services staff of the wilaya. The selected areas for the survey were, M'sila and its surroundings: 10 farms, Ouled Derradj: 34 farms and Magra: 20 farms surveyed. After tabulation, the collected data was coded and stored in a database designed with Microsoft Excel software 2013. The analysis concerned the descriptive statistics calculated for each of the parameters (means, standard deviations and proportions).

III– Results and discussion

The results obtained show that 97% of goat farming is conducted by men, 48% of whom are over 55 years old. As has been reported in several studies in Algeria, in Mediterranean regions or around the world (Mouhous *et al*., 2015; Todaro *et al*., 2015), livestock are mostly conducted in extensive mode, most often in association with sheep. The local race "Arabia" located in steppe, semi-steppe and highland areas, Guintar *et al*., (2018) is dominant in the farms surveyed. According to the breeders it is more adapted to the climate of the study area.

Mid-sized herds are the most frequent, 23.5% have 10 to 20 goats. Large herds are quite rare. However, 12.5% of the surveyed breeders have 70 to 80 goats and 5% have a population of over 100 animals.

93.4% of breeders sell males aged 6 –12 months or older, and keep only one male in the herd for reproduction.

A lack of technical skills of breeders and extension has been noted, this situation was previously reported by Kadi *et al*., (2016).

Goat meat is dedicated to breeders self-consumption and then for sale. Goats are sold in the market or in the farm on feet and like carcasses in butchers. Prices of goats are different according to their age and weight. Recently prices of goat meat and milk increased significantly. Milk is sold at 150 Algerian dinars the liter and goat meat is at 1400 local dinars the kilogramme, recently aligned to meat sheep. Bring together the two components: more productive orientation towards mixed farming (milk/meat) and the sale of young goats participates to sustain household cash flow and allow securing the farming system. This option was also reported by Sahraoui *et al*., (2016).

The majority of breeders surveyed (64%) practically only graze on steppe routes and stubble cereals. 36% of breeders distribute barley in addition to grazing (Fig. 1). Goats reared with sheep rarely benefit from feed supplement.

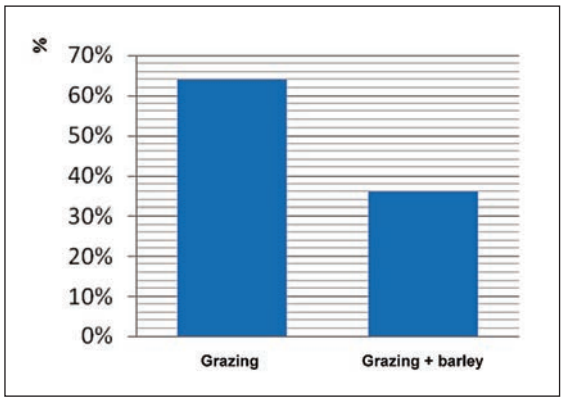

Fig. 1. Feeding mode of surveyed breeders.

The practice of rationing is not found in any of the farms surveyed which explains the low productivity in milk and meat of these farms. Watering is always available, drinkers are developed and water comes from wells and cisterns.

According to the results of the survey, 67% of breeders are oriented towards milk production, 22% towards the mixed type (meat-milk) and 11% are oriented towards the production of kids for fattening (Fig. 2). These three production systems meet three strategies followed by breeders. The majority of breeders (67%) raise goats for their milk. The surplus production is intended for sale. Kids goats, are destined for the market at a very young age. On the other hand, the mixed system farms) are interested in the two productions. In addition to milk, kids are then fattened for market. Finally, the third system is followed by these very few breeders (11%) who raise chevons for fattening. Often these breeders leave the milk of goats for their kids goats. They have some cows for their own consumption of milk. This configuration of breeding strategies is also reported by Mouhous *et al*., (2015) in the mountains of Kabylia (Algeria).

All the breeders feed the kids with the goats milk and 87% wean them at the age of 3-4 months. Kids can be sold from six months old or more. The price of goat meat has been aligned with that of sheep in the local market, which is a contribution to household cash flow.

An important demand of goat meat related to its medicinal and dietary virtues is observed. This meat is considered as a bio product**.** Among the grazed species in the study area, *Artemisia herba alba, Artemisia campestris, Peganum harmala, Ziziphus lotus, Medicago arborea, may* give organoleptic and therapeutic qualities to local goat meat.

According to the breeders responsesm ilk production of Arabia goat breed is about 1liter to1.5 liter per day. Produced milk quantities are low, 67% of the breeders use it for self-consumption.

Otherwise, our survey reveals that the majority of breeders do not pay fees for veterinary care of goats.

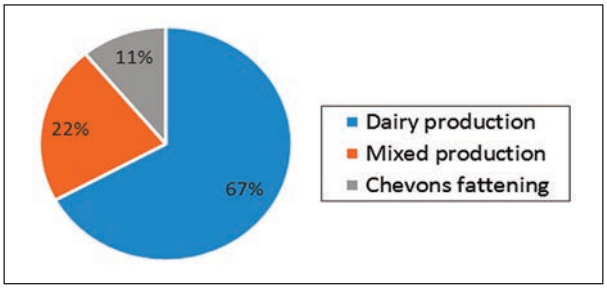

Fig. 2. Different Types of production (milk, meat or mixted).

IV – Conclusion

The study leads to several results: Farming conditions are often difficult and technical supervision is often weak in traditional farms, which explain low performances. Goat farming in the study area faces different constraints. Low rainfall, an insufficient food supply, a lack of livestock management and extension, lack of farmer training and financial assistance for this sector make this activity less attractive.

Low productivity could be improved by better farm management and by the use of selected breeds with higher potential. Extension and training for better livestock management are among the prospects to be considered. Goat farming contributes to improving household incomes and reducing rural exodus. The organization of a goat sector is necessary for the sustainability of goat farming. Several elements argue for a better profitability of this activity. Prices of meat and milk, new consumer trends, ancestral knowledge of local farmers could enhance the profitability of this sector. Goat called poor's cow could someday become rich's cow.

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Biodiversity and ecological conditions of rangelands for the local livestock system of Lemnos (Greece)

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Abstract. In contrast to most Aegean islands, Lemnos (482 km², Northeast-Aegean) is characterized by non-calcareous sandstones, marls and alluvial deposits. Prevailing land use is agriculture, chiefly for fodder production for sheep and goat husbandry. Apart from local cereal crop production, the animals depend on the island's rough grazing lands. In the project Terra Lemnia, we attempt to relate land-use systems, vegetation types and biodiversity patterns. In a first step, we collected a sample of 19 plot-based vegetation records of 100 m² each. We found chiefly three main land-cover types: (1) Low-shrub formation (phrygana) dominated by *Sarcopoterium spinosum*; (2) Low-growing dense-sward formation of perennial and annual grasses and herbs; (3) Heavily trampled and overgrazed patches dominated by unpalatable ruderal plants. *Sarcopoterium* phrygana (12 plots studied) comprise on average 62.3 vascular plant species per plot, low-growing dense swards (5 plots) 57.3 species. With up to 10 % (and sometimes more) of the island's known species pool represented in a single 100 m² plot, the phrygana and the low-sward rangelands of Lemnos have an extremely high alpha and moderate beta and gamma diversities. Patches of ruderal plants are rich in large flowers and inflorescences and have often long flowering periods (April-July). They thus attract numerous pollinators and other arthropods, and contribute quite essentially to the biodiversity richness of the island.

Keywords. Aegean islands – Grazing – Land-cover types – Phrygana – Rangeland diversity.

Biodiversité et conditions écologiques des parcours pour le système d'élevage local de Lemnos (Grèce)

Résumé. *Contrairement à la plupart des îles de la mer Égée, Lemnos (482 km², nord-est de la mer Égée) est caractérisée par des grès, des marnes et des alluvions non calcaires. L'agriculture est l'utilisation prédominante des terres, principalement pour la production de fourrage destiné à l'élevage des ovins et des caprins. Outre la production céréalière locale, les animaux dépendent des pâturages de l'île. Dans le projet Terra Lemnia, nous essayons de relier les systèmes d'utilisation des terres, les types de végétation et les schémas de biodiversité. Dans un premier temps, nous avons collecté un échantillon sur 19 enregistrements de végétation basés sur des parcelles de 100 m² chacun. Nous avons principalement trouvé trois types de couverture terrestre: (1) La* ***fo****rmation d' arbustes bas (phrygana) dominée par* Sarcopoterium spinosum*; (2) La formation à croissance lente et dense de graminées et de plantes herbacées vivaces et annuelles; (3) Des parcelles fortement piétinées et surpâturées dominées par des plantes rudérales désagréables. Sarcopoterium phrygana (12 parcelles étudiées) comprend en moyenne 62,3 espèces de plantes vasculaires par parcelle, des prairies denses à croissance faible (5 parcelles) de 57,3 espèces. Avec un maximum de 10% (et parfois plus) du pool d'espèces connues de l'île représentées dans une seule parcelle de 100 m², les prairies de phrygana et de pâturages à faible altitude de Lemnos présentent une diversité extrêmement élevée en alpha et des niveaux en bêta et gamma modérés. Les parcelles de plantes rudérales sont riches en grandes fleurs et inflorescences et ont souvent de longues périodes de floraison (avril à juillet). Elles attirent ainsi de nombreux pollinisateurs et autres arthropodes et contribuent de manière essentielle à la richesse de la biodiversité de l'île.*

Mots-clés. *Îles de la mer Égée – Pâturage – Types de couverture végétale – Phrygana – Diversité des pâturages.*

I – Introduction

Lemnos (Greece) is a North Aegean island, which shows a distinctive cultural, biogeographical and ecological character. It is the southernmost of the larger islands in the North Aegean and is well isolated from the neighbouring islands of Lesvos, Samothraki and Imbros. In contrast to most typical Aegean islands, Lemnos is characterized by gentle slopes, wetlands and a long coastline contributing to the formation of an extensive net of freshwater and brackish marsh formations especially in the eastern part. Unlike other large Aegean islands, Lemnos is hilly rather than mountainous (maximum 429 m a.s.l.). This gentle topography is mainly due to the absence of calcareous rocky landscapes and to the prevalence of volcanic, molasse (sandstones, marls) and psammitic rock formations on most of the island (Davis, 1959). The climate of the area is subhumid or almost semi-arid, with a mean annual precipitation of c. 500 mm. Frequent winds, blowing mainly from N or NE, contribute to the dry climate of the island.

The island of Lemnos conserves a high-level ecological value, based on a variety of natural vegetation formations but chiefly on human-made habitat types such as of arable and pastoral farmland. Cultivated crops include wheat, barley, grapes, cotton and sesame. The cereals are chiefly for fodder production. In Lemnos the main domestic grazing animals are sheep and goats. There are approximately 80,000 sheep and 12,000 goats that depend on the island's cereal crop production and on its rough pasturelands and low shrublands (phrygana). The type of grazer, its numbers and plant selectivity are important factors for floristic composition and patterns. Local breeds of sheep and goats, still extant in small populations on Lemnos and better adapted to the local climate and rough grazing conditions, range long distances and exert lower grazing pressure than imported breeds.

In the framework of the "Terra Lemnia" project supported by the "MAVA Foundation for Nature", our objective was to examine the status of biodiversity, in particular plant species composition and richness, and to assess the impacts of different land use, as a basis for establishing a system of effectively monitoring the impact (success) of all activities on biodiversity using bio-indicator species.

II – Methods

During April-May 2018, field work and collection of baseline data on the current status of biodiversity has been conducted on agro-pastoral land of selected rangeland areas of the island, including rangelands of the Natura 2000 site GR4110006 (Chortarolimni, wider area of Lake Alyki and Fakos Peninsula).

In the four broader study areas of Vigla, Fakos, Ifaisteia, Poliochni-Fisini, plus a fifth one in the communal farm 'Metropolis', 19 plots were studied in greater detail. Work was carried out in the selected sites by a team of experts and comprised plot sampling in rangelands of mainly phryganic and herbaceous plant communities. We collected plant specimens and completed floristic and vegetation sampling, using the method of Braun-Blanquet (1928), in similar rectangular plots of 10x10 m^2 as the other project collaborators were recording crop landraces, forage and fodder crops, birds and beneficial insects.

The 19 plots were delineated within semi-natural vegetation (rangeland). For these plots information concerning: (i) grazing intensity (high / medium / low / no grazing – abandoned) and (ii) grazing animal type (sheep, goats, both / local breeds or not), has been added.

III – Results and discussion

Preliminary results of this first fieldwork in 2018 included records of 285 species (including four on genera level) (Table 1). Some of the plants like *Elytrigia obtusiflora*, *Lotus hispidus*, *Medicago coro-*

nata, *Trifolium nigrescens*, *Trifolium tenuifolium* and *Vicia parviflora* were discovered for the first time on Lemnos Island. A taxonomic analysis shows that the recorded plant taxa belong to 32 plant families and 180 genera. The ten most common plant families are: Fabaceae (22%), Asteraceae (19%), Poaceae (14%), Caryophyllaceae (7%), Brassicaceae (5%), Lamiaceae (4%), Apiaceae (3%), Boraginaceae (2%), Euphorbiaceae (2%), Geraniaceae (2%) and Orchidaceae (2%). It is noteworthy that (i) the three first families, Fabaceae, Asteraceae and Poaceae represent 55% of the total flora registered and (ii) about 62% of the plant taxa are plants with annual or biennial life cycle (annuals, therophytes) and 38% perennials.

We found basically two types of rangeland on Lemnos: (i) Phrygana (low shrubland) dominated by *Sarcopoterium spinosum* of the phytosociological alliance *Hyperico olympici-Cistion cretici* was found widespread and chiefly on soils derived from weathered molasse; in places it occurs as successional stage on abandoned agricultural land; and (ii) more or less dense swards of herb-rich grasslands of the phytosociological order *Poetalia bulbosae,* that are common mainly on shallow soils over old volcanic (andesite) rocks. Both phrygana and herb-grasslands are very species-rich (62.3 and 57.3 species per 100 m² respectively) and especially rich in annual plants (thereophytes) (Table 1).

The very high percentage of therophytes is typical of Mediterranean phryganic and herbaceous vegetation (Panitsa *et al.,* 2003). Rauh (1949) and Browicz (1991) pointed out that the inhabitants *'brought lowlands and moderate slopes under cultivation and allowed steeper slopes to be overgrazed by sheep and goats*'. High percentages of therophytes and especially of annual leguminous species are indicators of long-term but moderate human interference in many Mediterranean rangeland ecosystems (Arianoutsou and Margaris 1981, Barbero *et al.,* 1990, Panitsa *et al.,* 2003). In Lemnos island, leguminous species contribute 17% on all recorded plant taxa and 21% of the therophytes.

Table 1. The ten most common plant species on the plots (n=19) including information to plant family and life form

Scientific name	Plant Family	Life form	Plot records
Sherardia arvensis	Rubiaceae	Therophyte	17
*Trifolium campestre**	Fabaceae	Therophyte	16
Cerastium glomeratum	Caryphylloceae	Therophyte	14
*Tordylium apulum**	Apiaceae	Therophyte	13
*Leontodon tuberosus**	Asteraceae	Hemicryptophyte	13
*Eryngium campestre**	Apiaceae	Hemicryptophyte	13
Dactylis glomerata	Poaceae	Hemicryptophyte	13
*Hymenocarpos circinnatus**	Fabaceae	Therophyte	12
*Galium aparine**	Rubiaceae	Therophyte	12
*Carlina corymbosa**	Asteraceae	Hemicryptophyte	12

*Insect-pollinated species.

A third land-cover type of rangelands comprises ruderalized patches of heavily trampled and overgrazed sites dominated by unpalatable plants such as *Asphodelus ramosus*, *Ballota acetabulosa*, *Euphorbia characias* along with various thistles. Patches of these ruderal plants have usually lower species diversity than the other formations but are rich in large flowers and inflorescences and have often longer flowering periods (April-July). In this long time interval, they thus attract numerous pollinators and other arthropods and contribute quite essentially to the richness of the island's faunal and floral diversity.

Such enormous variation in rangeland appearance and diversity reflected abiotic effects as well as differences in grazing intensity in different rangeland sample plots and areas, sometimes current land use intensity, sometimes the heritage of former locally overly high stocking densities. Our preliminary results revealed that such intensity-dependent patterns may be found within a single

sample area or even farming unit, where overgrazed rangelands next to former or extant farmsteads and lairs being dominated by unpalatable plants such as *Asphodelus ramosus*, and *Sarcopoterium spinosum* rangelands ('phrygana') widespread in the surroundings. Long-term abandonment of rangelands appears to lead to a denser subshrub (and shrub) canopy and to a lower proportion of annual plants, a process resulting in a net loss of species density.

IV – Conclusions

The Terra Lemnia project seeks to develop scientifically solid, yet practical, guidelines for biodiversity friendly, low input, farming methods in Lemnos, building on good practices already found in the island today. Fieldwork in 2018 has shown that such methods may also be economically viable – and farmers can acknowledge this, a fact that leaves room for optimism that the diversity of Lemnian pastoral and agroecosystems can indeed be maintained and even enhanced.

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Caractéristiques de production de l'élevage ovin dans la région semi-aride de Sidi Bouzid en Tunisie

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Résumé. Sidi Bouzid est une région semi-aride spécialisée dans l'élevage ovin. Le présent travail vise à caractériser les systèmes de production ovine dans cette région. Une enquête a été menée sur un échantillon de 111 éleveurs des ovins. Les résultats obtenus ont montré que pour la majorité des éleveurs enquêtés (94,5%), l'agriculture est l'activité principale et la source de leurs revenus. Les éleveurs dont la superficie agricole est inférieure à 10 ha représentent environ 45,4% et 9,1% n'ont pas de superficie agricole (sans terre). L'élevage ovin est soit pratiqué seul (42,7%), soit associé à l'élevage caprin (31,8%) ou bovin (20,9%), soit associé au deux à la fois. Les deux tiers des exploitants ont moins de 10 brebis, et près de 30% avec un effectif inférieur à 50 brebis. La Barbarine et la Queue Fine de l'Ouest sont les races ovines les plus dominantes avec 53,8% et 44,8%, respectivement. 76,4% des agriculteurs utilisent les ressources pastorales pour nourrir leurs animaux. La transhumance est devenue rare et concerne seulement 21% des troupeaux visités. Les ressources alimentaires alternatives utilisées sont: foin d'avoine (61,8%), paille (34,5%), grignons d'olives (53,6%), orge en vert (11%), cactus (28,2%) et son de blé (42%). En ce qui concerne les agneaux, la période d'allaitement a été en moyenne de 4,87 ± 1,4 mois. La majorité des agriculteurs (67,3%) vendent les agneaux à un âge de 6 mois, seulement 32,7% vendent les agneaux après une période d'engraissement (plus de 6 mois). Les agneaux sont vendus à un âge moyen de 10,6 ± 6 mois et à un poids moyen de 29,8 ± 11,2 kg. Le foin, la paille, le grain d'orge et le concentré commercial ont essentiellement été utilisés pour engraisser les agneaux, et le pâturage est modestement utilisé (23%).

Mots-clés. Élevage ovin – Système de production – Alimentation – Ressources pastorales – Semi-arides.

Production characteristics of sheep farming in the semi-arid region of Sidi Bouzid, Tunisia

Abstract. *Sidi Bouzid is a semi-arid region specialized in sheep farming. The present work aims to characterize sheep production systems in this region. A survey was conducted on a sample of 111 sheep farmers. The results showed that for the majority of farmers surveyed (94.5%) agriculture was the main activity and the source of their income. Farmers with agricultural area less than 10 ha represent about 45.4% and 9.1% did not have any agricultural area (without land). Sheep farming is either practiced alone (42.7%) or associated with goat (31.8%) or cattle (20.9%) farming or associated to both. Two-thirds of the farmers had less than 10 ewes, of which almost 30% have a yield of less than 50 ewes. The Barbarine and Queue Fine de l'Ouest breeds was the most dominant sheep with 53.8% and 44.8%, respectively. Pastoral resources were used by 76.4% of farmers to feed their animals. Transhumance has become scarce and affects only 21% of the visited flocks. Alternative food resources were also used: such as oat hay (61.8%), straw (34.5%), olive cake (53.6%), green barley (11%), cactus (28.2%) and wheat bran (42%). For lambs, suckling period averaged 4.87±1.4 months. The majority of farmers (67.3%) sell lambs at 6 months old and only 32.7% sell lambs after a fattening period (more than 6 months). Lambs were sold at an average age of 10.6±6 months and at a weight of 29.8±11.2 kg. Hay oat, straw, barley grain and commercial concentrate were essentially used to fatten lambs and pasture was moderately used (23%).*

Keywords. *Sheep farming – Production system – Feeding – Pastoral resources – Semi-arid.*

I – Introduction

L'élevage ovin en Tunisie joue un rôle important aussi bien dans l'économie nationale que pour la population rurale. Ainsi, l'élevage ovin est une activité largement pratiquée et représente une source de revenu pour de nombreuses familles voir même pour des régions entières. En effet, sur 515 880 exploitants, 274 000 élèvent des ovins soit 53,11% des exploitations agricoles (Mohamed-Brahmi *et al*., 2010). En plus, La production de viande ovine représente en moyenne 40 à 45% de la production de viande rouge soit 25% de la production totale de la viande (GIVLait, 2017). D'autre part, plus que trois quarts du cheptel ovin est détenue par des exploitations de petite taille (superficie inférieure à 20 ha) et situées dans les zones semi-arides et arides (Mohamed-Brahmi *et al*., 2010).

La viande d'agneau de Sidi Bouzid est la plus appréciée et préférée par le consommateur tunisien, surtout pour la fête de l'Aïd El Kébir, en raison de sa qualité supérieure et sa valeur santé. L'élevage ovin est fortement ancré dans les traditions de cette région et il est basé essentiellement sur l'exploitation des parcours naturels. Toutefois, courant ces dernières décennies, cet élevage a connu une mutation profonde suite à la transformation des parcours en périmètres irriguées et aux changements climatiques (Atti, 2011, Ben Salem, 2011). Les systèmes de production de l'agneau se sont orientés vers un engraissement des agneaux en bergerie avec du foin et de l'aliment concentré, ce qui a conduit à la perte de la particularité de l'élevage ovin dans cette région. Alors, pour une gestion raisonnée de l'avenir de l'élevage ovin dans cette région, une caractérisation des nouveaux systèmes d'élevage ovins est indispensable pour mieux identifier et valoriser ses systèmes de production. L'objectif de ce travail est ainsi de caractériser les systèmes d'élevage ovins dans la région de Sidi Bouzid.

II – Matériel et méthodes

Dans le but d'identifier et constituer une base de données sur les systèmes d'élevage ovin dans la région de Sidi Bouzid, une enquête a été réalisée auprès d'un échantillon de 111 éleveurs repartis sur 11 délégations (Tableau 1) en collaboration avec l'Office d'élevage et des pâturages (OEP) et la Cellule territoriale de vulgarisation (CTV) du Gouvernorat de Sidi Bouzid. Les élevages ont été choisis sur la base de localisation géographique, de l'importance de l'activité ovine dans la délégation et de la réceptivité des éleveurs. Le questionnaire de l'enquête vise à recueillir des informations sur: (i) lL'identification de l'exploitant (âge, niveau d'instruction, activité principale…) ; (ii) la typologie de l'exploitation (superficie, ancienneté, activité agricole…) ; et (iii) les caractéristiques de l'élevage (effectif, race, alimentation, ligne de conduite…).

Tableau 1. Répartition des éleveurs enquêtés par délégation

Délégation	Nombre d'éleveurs
Sidi Bouzid (Est et Ouest)	43
Awled Hafouz	7
Jelma	13
Essabala	8
Ben Aoun	5
Bir El Haffey	5
Regueb	5
Maknassi	5
Manzel Bouzaiane	7
Essouk Jedid	4
El Mazouna	9

III – Résultats et discussion

Les caractéristiques générales des exploitations sont récapitulées dans le Tableau 2. Le dépouillement des données de l'enquête nous permet de dégager les résultats suivants :

1. Identification des exploitants

Selon l'activité principale des éleveurs enquêtés, deux grandes catégories sont distinguées. Une première catégorie d'éleveurs (94,5%) pour lesquels l'élevage constitue la source principale de revenus. Une seconde catégorie d'éleveurs (5,5%) pour lesquels l'élevage ovin constitue un mode d'épargne et non pas une source principale de revenus. La répartition des éleveurs selon l'âge montre que 80% des éleveurs visités ont un âge supérieur à 40 ans et que la moyenne d'âge est de 53,05 ±14,92 ans avec un minimum de 22 ans et un maximum de 91 ans. Concernant le niveau d'instruction, la majorité des éleveurs (80%) n'ont pas dépassé le niveau primaire alors que le niveau supérieur ne représente que 2%. Alors, on constate que le niveau d'instruction de la plupart des éleveurs est faible ne permettant pas une bonne technicité pour pouvoir réussir la conduite du troupeau ovin. Le Tableau 2 indique également qu'environ 78% des éleveurs visités ont une ancienneté dans l'élevage ovin qui dépasse 15 ans, ceci constitue un avantage pour les exploitants qui semblent hériter l'activité d'élevage ovin de père en fils et qui ont probablement de l'expérience qui leur permet de résoudre et de prendre les bonnes décisions afin de réussir leur élevage. Les éleveurs visités sont classés en trois groupes selon leurs activités : des naisseurs (56,36%), des naisseurs-engraisseurs (39,09) et le reste des engraisseurs (4,55%).

Tableau 2. Caractéristiques des exploitants et des exploitations visités

Identification des exploitants				
Classe d'âge des exploitants	< 40 ans 20%	40-60 ans 47,27%		> 60 ans 32,73%
Niveau d'instruction	Analphabète 36%	Primaire 46%	Secondaire 16%	Supérieur 2%
Classe d'ancienneté	< 5 ans 4,5%	5-10 ans 7,3%	10-15 ans 10%	> 15 ans 78,2%
Identification des exploitations				
Superficie agricole utile	0 ha 9,1%	< 10 ha 45,4%	10-50 ha 26,4%	> 50 ha 19,1%
Type d'élevage pratiqué	Ovin 42,73%	Ovin+caprin 31,91%	Ovin +bovin 20,91%	Ovin+caprin+bovin 4,55%
Races ovines élevées	Barbarine 53,8%	Queue Fine de l'Ouest 44,8%		Croisée 53,8%
Taille du troupeau ovin (Unité femelle)	< 50 29,25%	50-100 36,79%	100-150 13,21%	> 150 20,75%

2. Identification des exploitations

L'élevage ovin est pratiqué par des petits et moyens exploitants. En effet, environ la moitié des éleveurs visités ont une superficie agricole inférieure à 10 ha et 29,3% des éleveurs ont moins de 50 brebis. Alors que seulement 21% des éleveurs détiennent plus que 150 brebis. En plus, un dixième des éleveurs n'ont pas de terre et n'ont pas accès au parcours. Pour cette dernière classe, la disponibilité des ressources alimentaires est dépendante du marché. Par ailleurs, ceci représente une contrainte pour le développement et la durabilité du secteur de l'élevage ovin dans cette région. Généralement, l'élevage ovin est pratiqué soit seul (43%), soit associé à un élevage caprin (31,8%) ou à un élevage bovin (21%) soit associé aux deux élevages à la fois. Quant aux races ovines élevées,

la race Barbarine est la plus dominante avec 53,8% contre 44,8% pour la Queue Fine de l'Ouest et 1,4% pour les races croisées. Ceci indique que la tendance de substitution de la Barbarine par la queue fine de l'Ouest s'est étendue au gouvernorat de Sidi Bouzid probablement en raison de certaines préférences des consommateurs pour une carcasse maigre et surtout sans queue grasse.

3. Ligne de conduite

Les troupeaux d'ovins sont conduits en système d'élevage basé essentiellement sur le pâturage, caractérisé par des rations constituées de parcours naturels, foin, chaumes, résidus de récolte et de verdure (orge en vert, avoine), avec une variabilité importante dans la nature de des ressources alimentaires en fonction de l'activité principale de l'exploitation. De même, la transhumance a perdu de son importance et ne touche que 21% des troupeaux de la région. Par ailleurs, des ressources alimentaires alternatives sont utilisées : foin (61,8%), paille (34,5%), grignons d'olive (53,6%), orge en vert (11%), cactus (28,2%), son de blé (42%).La lutte continue est pratiquée par la moitié (51,8%) des éleveurs, alors que la lutte contre saison (printemps) est pratiquée par 40% des éleveurs. L'effet bélier n'est pratiqué que dans les troupeaux de grande taille. Seule une minorité (8%) pratique la lutte de saison (automne).

En ce qui concerne les agneaux, la période d'allaitement est en moyenne de 4,87 ± 1,4 mois. A cause de la sècheresse et de la hausse des prix des céréales, la majorité des éleveurs (67,3%) vendent leurs agneaux à un âge de 6 mois, 20,9% vendent leurs agneaux entre 6 et 12 mois, alors qu'un faible pourcentage des éleveurs (11,8%) élève les agneaux plus qu'un an. Les éleveurs qui utilisent les ressources pastorales pour l'alimentation de leurs troupeaux représentent 76,4%. Par ailleurs, pendant la période d'engraissement, le pâturage est peu utilisé (23%), alors que d'autres ressources sont utilisées comme le foin (63,5%), la paille (9,6%), l'orge grain (44,5%) et le concentré d'engraissement (27%).

IV – Conclusions

L'élevage ovin dans la région de Sidi Bouzid est pratiqué par des petits et moyens exploitants assez âgés et ayant une expérience acceptable. Par ailleurs, l'engraissement des ovins est caractérisé par un apport de quantités importantes d'aliment concentré. Cependant, le coût de production en bergerie est élevé, d'où l'importance de trouver des produits de substitution particulièrement des sources locales d'azote pour remplacer les matières premières importées d'une part. D'autre part, il est nécessaire d'améliorer la gestion des parcours naturels dans le but de préserver un produit de qualité dans de nouveaux systèmes de production.

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Analyse typologique des transhumances ovines de la région de Djelfa : Quel type pour quel avenir

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Résumé. La transhumance constitue une pratique courante de l'élevage ovin agropastoral. Elle permet l'accès à des pâtures supplémentaires. Toutefois, cette pratique qui contribue à l'équilibre des systèmes alimentaires connait des difficultés. Pour se maintenir, elle diversifie ses stratégies de mobilité. Notre questionnement porte sur les circuits, orientions et saisonnalités des déplacements actuels (ou néo-transhumances). Pour se saisir de cette réalité nous avons eu recours aux données spatiotemporelles de différentes institutions (Ministère de l'Agriculture, Commissariat aux steppes etc.) et de données de 30 enquêtes participatives auprès des éleveurs transhumants de la région de Djelfa. Les résultats de nos études ont mis en évidence 5 types de transhumance : continue (6 % de l'effectif total mobile), intracommunautaire (43 %), d'hiver (20 %), d'été (16 %), et traditionnelle (14 %). Ces déplacements permettent d'assurer 25 à 55 % de la couverture fourragère pour les animaux. Les agropasteurs adaptent sans cesse leurs orientations/circuits. Cependant, la réduction des espaces pastoraux et les incertitudes climatiques rendent la transhumance vulnérable. Une harmonisation d'intérêts divers et de régulation des accès aux ressources pourrait potentialiser ces mobilités.

Mots-clés. Système d'élevage ovin – Transhumance – Gouvernance – Contribution – Steppe.

Transhumance agropastoralists in sheep of Djelfa. What type for what future?

Abstract. *Transhumance is a common practice in agropastoral sheep farming. It provides access to additional pastures. However, this practice, which contributes to the balance of food systems, is experiencing difficulties. To maintain itself, it is diversifying its mobility strategies. Our questioning concerns the circuits, orientations and seasonality of current movements (or neo-transhumances). To address this reality, we used spatiotemporal data from different institutions (Ministry of Agriculture, Steppe Commission, etc.) and data from 30 participatory surveys among transhumant livestock farmers in the Djelfa region. The results of our studies highlighted 5 types of transhumance: continuous (6% of the total mobile workforce), intra-community (43%), winter (20%), summer (16%), and traditional (14%). These movements make it possible to provide 25 to 55% of the forage cover for animals. Agropastoralists are constantly adapting their orientations/circuits. However, the reduction of pastoral areas and climatic uncertainties make transhumance vulnerable. Harmonisation of various interests and the regulation of access to resources could potentiate these mobilities.*

Keywords. *Sheep rearing system – Transhumance – Governance – Contribution – Steppe.*

I – Introduction

L'agropastoralisme steppique semblait s'être fortement sédentarité et la pratique de la transhumance diminuer d'après de nombreuses observations (Benchérif, 2018). Pourtant, au cœur de la steppe environ 40 à 70 % des ovins transhument (selon les régions). L'émergence des logements en dur a généré des confusions (Bourbouze, 2018). Certes une partie de la famille reste toute l'année dans ces logements, mais une partie des adultes assurent les mobilités. Il est fréquent de voir rester les grands parents et les jeunes scolarisés. L'accès à des ressources par des néo-tran-

shumances apparait indispensable pour bon nombre d'élevage ovin. Ce secteur conserve un poids essentiel pour l'économie nationale. 80 % de l'effectif national se trouve dans les steppes avec plus de 27 millions de têtes (Kanoun, 2016). La pratique de la mobilité permet aux éleveurs de gérer des déséquilibres saisonniers et interannuels. Selon Thébaud *et al.* (2018), "la mobilité permet de maintenir le capital reproducteur et de renforcer sa résilience en situation de crise". Elle rencontre toutefois des adversités qui se conjuguent : i) l'organisation socioéconomique a changé, déjà par le recours aux bétaillères ; ii) les règles d'accès aux pâturages de transhumances ont évolué ; les parcours sont altérés ; etc. En conséquence, la viabilité de cette pratique se pose (Hirche *et al.*, 2007 ; Aidoud *et al.*, 2011). Afin de saisir leur niveau de fragilité, nous avons cerné leur organisation spatiotemporelle par une approche multidisciplinaire. Nos études portent sur le redéploiement des mobilités selon leurs contraintes entre 2001 et 2015. Nous avons commencé par caractériser les formes de mobilités.

II – Méthodologie et sources utilisées

Le travail de recherche s'est basé : (i) sur des données spatiotemporelles issues de différentes institutions étatiques toutes chargées de la collecte d'informations sur l'élevage ; (ii) d'observations directes et de 30 enquêtes participatives (Chevalier et Buckles, 2008) auprès d'éleveurs transhumants dans le territoire des Ouled Beidha de la région de Djelfa. Cette zone se caractérise par un effectif de 3 242 760 brebis réparties dans 15 820 élevages qui pratiquent la transhumance. Ils représentent près de 65 % des éleveurs de la région (CAD, 2017). Dans cette région la pratique de la mobilité se maintient. Cela peut s'expliquer par : (i) des sécheresses répétitives et froids rigoureux en hivers au niveau des terroirs d'attaches ; (ii) l'extension des cultures sur les terres de parcours dans ces mêmes terroirs (Kanoun, 1997). Les données géographiques des mobilités ont traité avec ArcGis afin d'obtenir des fichiers "*shapefile*" insérés dans le texte sous forme d'images.

III – Résultats et discussion

1. Evaluation des apports fourragers locaux et de transhumance

De 2001 à 2015, les ressources pastorales ne couvrent en moyenne que 44 % (σ : 12) des besoins alimentaires des animaux (Tableau 1). La dégradation de la végétation pastorale s'avère prononcée (Aidoud *et al*., 2011 ; Daoudi *et al.*, 2015 ; Hourizi *et al.*, 2017). Les steppes sont à présent insuffisantes pour nourrir l'ensemble des animaux surtout en périodes hivernales et estivales (HCDS, 2010). L'apport par la pâture en "terroir d'attache" apporte 44 % des ressources fourragères sur l'année. D'où le recours à la pratique de la transhumance par 65 % des éleveurs de Djelfa (CAD, 2017), qui couvre en moyenne 31 % (σ : 5) de la couverture des besoins alimentaires des animaux (Tableau 1). En conséquence, les ovins en transhumants sont complémentés.

Tableau 1. Contribution des ressources alimentaires locales et de la transhumance

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Cta%	32	31	45	48	39	40	44	42
CT%	32	27	28	25	31	40	35	33
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	
Cta%	72	66	56	40	37	36	35	
CT%	18	30	33	38	34	31	32	

Source : DSA de Djelfa + Nos traitements (2016) selon méthode d'estimation de l'INRAA (Kanoun, 2016) : (0.66 UF/tête/jour) x durée de la transhumance. Cta contribution dans le terroir d'attache ; CT contribution pendant la transhumance.

2. Evolution typologique de la transhumance ovine des éleveurs de Djelfa

Par le passé, la steppe constituait la seule ressource alimentaire des animaux. La transhumance était pendulaire jusqu'aux années 1990 : l'été au Nord vers le Tell "Achaba" et l'hiver au Sud vers le Sahara "Azzaba" (Bencherif, 2011 ; Benedir, 2015). Des facteurs ont affecté cette pratique : nouvelles régulations foncières, aléas climatiques, aménagement du territoire, etc. Il en résulte à présent des conflits d'usages des terres (Comby, 2017). Les logiques de déplacements ont perdu leur régularité dans le temps et l'espace (Kanoun, 2016). Les sites de transhumance dépendent d'opportunités fourragères et de moyens : camion, bétaillère, citerne d'eau, etc.

Les différentes transhumances ont été caractérisées grâce à 30 entretiens participatifs. Des données obtenues nous avons dressé une carte (1) des itinéraires de transhumance du cheptel ovin de la région de Djelfa et la répartition des cheptels et éleveurs des différents types de transhumances (Tab. II). Le cheptel mobile en 2015 se situait autour de 69 % de l'effectif total de la région, soit 2 242 760 têtes (Kanoun, 2016). Le reste de l'effectif, 1 007 617 têtes, était conduit selon un mode d'élevage sédentaire.

Tableau 2. Typologie et taille des effectifs de troupeaux ovins transhumants de Djelfa

Types	Catégories	Effectifs (têtes)	% t ovin	Rang	% éleveurs
1	Transhumance pendulaire	324 276	14	4	12
2	Transhumance d'Hiver	453 986	20	2	13
3	Transhumance d'Eté	356 704	16	3	19
4	Transhumance intracommunautaire	972 828	43	1	45
5	Transhumance continue	134 966	6	5	11
Total		2 242 760			

Source : DSA de Djelfa + calculs 2016.

- **Type 1**. T. pendulaire : se caractérise par deux grands mouvements saisonnière durant l'année : N & S (100 à 300 km de distance/camions). Elle rencontre des difficultés comme : i) la dérégulation d'accès aux parcours ; ii) le convoyage et la complémentation des animaux devenue nécessaire, etc. Elle devient vulnérable.
- **Types 2.** T. hivernale : Elle s'oriente vers les parcours présahariens, où le climat est plus clément et favorable à la période d'agnelage. Les steppes d'altitude des terroirs d'attache connaissent des hiver froid (Salemkour *et al.,* 2016). Ainsi, la végétation des parcours des territoires d'attaches se repose.
- **Type 3.** T. estivale : est localisée au nord de la Steppe. Les pâtures sont composées de résidus de cultures céréalières : chaumes et céréales sinistrées (Fig. 1). L'accès à ces ressources est monétarisé et leurs prix peuvent augmenter lors de sécheresses.
- **Type 4.** Transhumance intracommunautaire : Elles sont de modestes amplitudes. Ce mode de conduite concerne les terres appartenant aux différentes communautés situées dans les steppes des terroirs d'attache. Les bergers locaux ont tendance à privilégier les déplacements de faibles amplitudes. Cette pratique de mobilité s'est développée, mais elle induit des dégradations et des conflits sur une ressource naturelle déjà menacée.
- **Type 5.** Transhumance continue ou néo-nomadisme : La mobilité dépend des opportunités fourragères pastorales. Toutes les terres de parcours (même au niveau nationale) sont des zones d'accueil potentielles. Ces éleveurs font preuve de flexibilité relationnelle pour s'adapter aux situations d'incertitudes. Ils disposent de troupeaux de grande taille (> 300 têtes) et de moyens motorisés qui leur permet de faire face à diverses situations. Les déplacements de courte et longue amplitudes sont l'une des caractéristiques de ce type.

3. Appréciations sur les orientations des transhumances des agropasteurs

– **Nord – sud, d'automne-hiver :** de longues distances pour contourner la concurrence sur l'usage des pâturages courants. En 2016 à 2019, les éleveurs de Djelfa ont été à Tindouf et Illizi. Ces régions étaient autrefois inaccessibles aux éleveurs (manque moyens : citerne, bétaillère, etc.). De plus, grâce au téléphone les pasteurs transhumants peuvent rester informé à distance sur : la disponibilité des ressources végétales, les cours des aliments du bétail.

– **Mobilité de printemps :** soit sur les parcours de Djelfa, Naama (Djebel Aissa) Bérine, M'Sila, etc., dominés par des annuelles et des plantations pastorales (Huguenin *et al*., 2017) ; ou soit dans le Tell. L'accès aux ressources est payant. Les plantes éphémères sont très appréciées et très appétées par les ruminants (Chehma *et al.*, 2008).

– **Mobilité d'été :** longue amplitude, au nord, en régions céréalières où les troupeaux pâturent les résidus de cultures (Fig. 1). Cependant, le développement de la céréaliculture en terre steppique dans divers "terroirs d'attache" a également transformé cet espace pastoral en sites d'accueil de transhumance durant la période estivale (Aidoud-Lounis, 1997 ; Huguenin *et al.*, 2015).

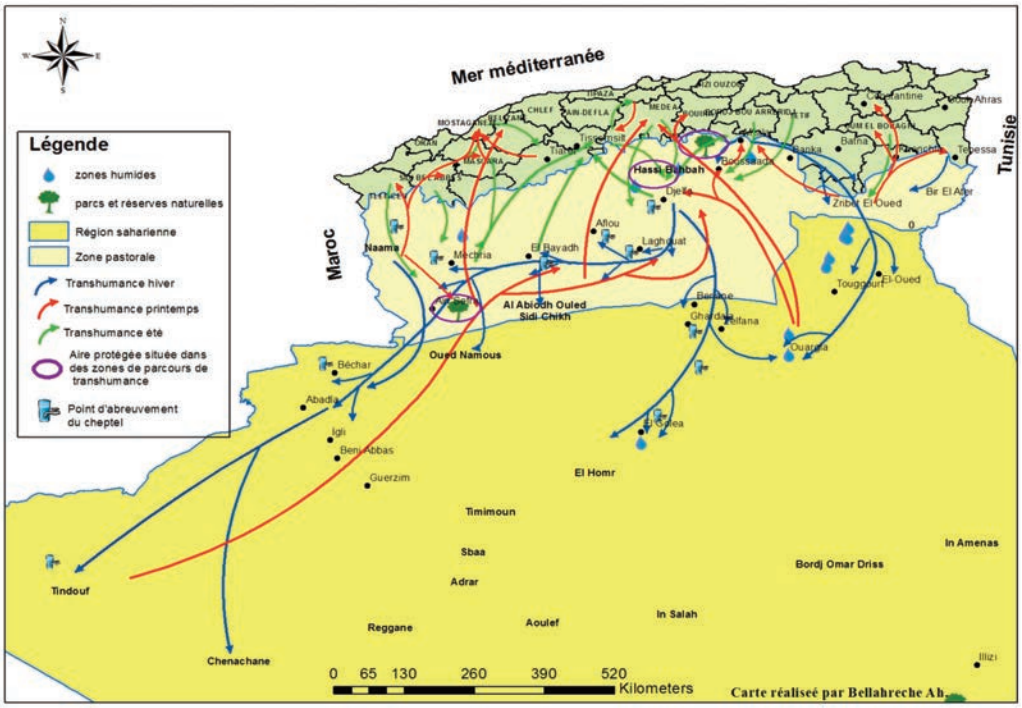

Fig. 1. Itinéraires de transhumance du cheptel ovin de la région de Djelfa. (Source : INRAA Djelfa).

4. Transhumance et durabilité : quelle lecture

Nous confirmons les contraintes auxquelles les transhumances sont confrontées, notamment : La réduction du disponible fourrager (dégradation du couvert), et la diminution des aires de pâturages en raison du développement des mises en cultures sur les terres de parcours (Bessaoud, 2013 ;

Benedir, 2015 ; Huguenin *et al.*, 2017). Le maintien des transhumances dépendra de l'augmentions de ses charges : complémentation des animaux, coûts du transport, rémunération des bergers, location des chaumes et parcours (Kanoun, 2016). De plus, l'absence d'une régulation des parcours (étatique ou associative) favorise l'insécurité foncière et des spéculations foncières. Cela complexifie la gestion de la transhumance. Pour trouver des perspectives favorables, des nouvelles formes de gouvernance collectives seraient à prospecter (Marty et Bonnet, 2006 ; IUCN, 2013).

IV – Principales conclusions et perspectives

L'étude d'un effectif de 2 242 760 têtes faisant une transhumance, nous a permis identifier 5 types de transhumance/mobilité : continue (6 %), intracommunautaire (43 %), d'hiver (20 %), d'été (16 %), et pendulaire (14 %). L'état dégradé des parcours d'accueil oblige les éleveurs à avoir recours à la complémentation systématique pendant la transhumance, car l'apport alimentaire des pâturages lors des transhumances ne couvre que 30 à 40 % des besoins des animaux. Pourtant elle s'avère encore la seule façon de mettre en valeur les vastes espaces pastoraux. Mais elle se révèle de plus en plus vulnérable, car elle est menacée par une pression foncière grandissante et par l'absence d'une régulation partagée entre les différends concernés (utilisateurs, services d'accompagnement ou de médiation, etc.). Des modes de conduite coordonnés des transhumances qui seraient couplés à des opérations de restauration/réhabilitation de certains parcours mériteraient d'être étudiés.

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Effect of the intake of carotenoids and tocopherols on the deposition in the suckling lamb

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Abstract. Carotenoids, present in great quantities in fresh forages, have been proposed as tracers of the feeding system in growing lambs. The aim of this study was to assess the transfer of carotenoids and tocopherols from the ewes' milk to the tissues of the suckling lambs(slaughtered at 10-12 kg LW). The intake of carotenoids and tocopherols of the lambs was estimated from the weekly milk production and the concentration of the respective analytes in milk. The content of carotenoids and tocopherolswas determined in the subcutaneous and perirenal fat, muscle and liver of the lamb. The lambs were classified in 4 groups according to the intake of carotenoids, retinol and tocopherol from milk.The contents of lutein and retinol in the tissues increased with the intake of the respective analyte (P<0.05 to P<0.001). The intake of α-tocopherol was reflected in deposition in the liver (P<0.001), muscle, subcutaneous fat (P<0.01) and perirenal fat (P<0.05). However, only the contents of γ-tocopherol in the subcutaneous fat were affected by the intake of the analyte, although not clearly (P<0.05). The deposition of the analytes depended on the tissue.

Keywords. Lutein – Retinol– Milk – Muscle – Fat.

Effet de l'ingestion de caroténoïdes et de tocophérols sur la deposition chez l'agneau de lait

Résumé. *Les caroténoïdes présents en grande quantité dans les fourrages frais, ont été proposés comme traceurs du système d'alimentation des agneaux en croissance. L'objectif de cette étude était d'évaluer le transfert de caroténoïdes et de tocophérols du lait de brebis vers les tissus des agneaux allaités (abattus à 10-12 kg de poids vif). L'apport en caroténoïdes et en tocophérols des agneaux a été estimé à partir de la production hebdomadaire de lait et de la concentration des analytes respectifs dans le lait. La teneur en caroténoïdes et en tocophérols a été déterminée dans la graisse sous-cutanée et périrénale, le muscle et le foie de l'agneau. Les agneaux ont été classés en 4 groupes en fonction de la consommation de caroténoïdes, de rétinol et de tocophérol du lait. La teneur en lutéine et en rétinol dans les tissus augmentait avec la prise de l'analyte respectif (p <0,05 à p <0,001). L'apport d'α-tocophérol se reflétait dans les dépôts dans le foie (P <0,001), le muscle, la graisse sous-cutanée (P <0,01) et la graisse périrénale (P <0,05). Cependant, seulement les teneurs en γ-tocophérol dans le graisse sous-cutanée ont été affectés para la ingestion de γ-tocophérol, mais pas clairement (P <0,05). Le dépôt des analytes dépendait du tissu.*

Mots-clés. *Lutéine – Rétinol – Lait – Muscle – Graisse.*

I – Introduction

Reintroducing the grazing management in sheep farms increases farm self-resilience, profitability and sustainability(Ripoll-Bosch *et al*., 2014), besides provides the fulfilment of the demands of the consumers for animal products from grass-based systems, which are considered safe, natural and respectful of animal welfare (Prache*et al*., 2005). The consumers, however, demand guarantees of the feedstuffs given to the animals, thus it is necessary to look for tools that allow tracing the feeding system of animals.

Carotenoids and liposoluble vitamins in the animal tissues have been studied to trace forage-feeding in ovine (Prache*et al*., 2005; Alvarez *et al*., 2014) as they are present in important amounts in the green forage and can not be synthesized by animals. Carotenoids and tocopherolsin forages, which differ among species, preservation methods and phenological stages, are transferred through the milk to the lamb (Nozière *et al*., 2006). They are deposited in the lambs' tissues, but differently depending on the tissue studied (Kasapidou *et al*., 2009). The aims of this study were to studythe transfer of carotenoids and tocopherols from the ewes' milk to the tissues of the suckling lambs.

II – Materials and methods

The experimental and slaughter procedures were approved by the Animal Ethics Committee of the Research Centre and met the guidelines of Directive 2010/63/EU (European Union, 2010) on the protection of animals used for experimental and other scientific purposes.

The experiment was conducted in La Garcipollera Research Station located in the mountain area of the Spanish Pyrenees (North-East Spain, 42º 37' N, 0º 30' O, 945 m a.s.l.).Thirty-nine pairs of dams-lambs were used.Two groups of 10 suckling lambs grazed with their dams in adjacent permanent pastures. The remaining 19 suckling lambs were stalled indoors with their dams in 2 pens, where pasture hay was offered to the ewes *ad libitum*. All the ewes received 300 g ewe^{-1} d^{-1} of concentrate (10.3 MJ Metabolisable energy kg^{-1} 14% crude protein as fed basis). The experiment lasted from birth until the lambs reached 10-12 kg, when they were slaughtered in the experimental abattoir of CITA research station.

Milk intake (Lobón *et al*., 2017) and the concentration of carotenoids, retinol and tocopherols in the milk (Bertolin *et al*., 2018) were used to calculate the intake of carotenoids and tocopherols of the lambs and grouped into 4 groups with increasing intakes (Class 1 to 4, in increasing order, Table 1). Samples of the subcutaneous and perirenal fat, longissimus thoracis muscle and the liver were obtained from the carcasses that had been cooled at 4 ºC for 24 h in the dark. Samples were immediately vacuum-packed and frozen at -80 ºC. Muscle and liver samples were lyophilized. The analytes were determined by liquid chromatography as described in Bertolin *et al*. (2018). Carotenoids and retinol were detected by absorbance at 450 nm and 325 nm, respectively; and tocopherols by fluorescence emission at λ_{exc} = 295 and λ_{emi} = 330 nm. β-carotene, lutein, retinol and tocopherols were identified by comparison of their retention times and spectral analyses and were quantified by external calibration with those pure standards.

Table 1. Intake of lutein, retinol and tocopherols according to the category

	1	2	3	4	s.e.	P-value
n	10	10	10	9		
Lutein, ng	16^{d}	118^{c}	344^{b}	615^{a}	14.8	0.001
Retinol, mg	2^{d}	3^{c}	5^{b}	9^{a}	0.19	0.001
α-tocopherol, mg	9^{d}	17^{c}	24^{b}	36^{a}	0.7	0.001
γ-tocopherol, mg	0.6^{d}	0.9^{c}	1.2^{b}	1.9^{a}	0.04	0.001

Within a line, means with different letter differ at P<0.05.

Data were analyzed using the SAS statistical software (SAS V.9.3). Normality of the residues of the contents was verified except for of α-tocopherol in the muscle and the contents of γ-tocopherol in the liver and perirenal fat. For these analytes, means were compared with the Kruskal–Wallis non-parametric test of the NPAR1-WAY procedure.The contents with normal distribution of the residues were tested by ANOVA using the GLM procedure of SAS with the group of intake as fixed effect. Least square means and their associated standard errors were estimated. For all tests, the level of significance was set at 0.05. Trends were discussed when P-values were < 0.10.

III – Results and discussion

The intake of lutein, retinol and α– and γ–tocopherol of the lambs differed among the groups (Table 1). Lutein content in the liver and muscle increased according to the intake (P<0.001) (Fig. 1). It can be hypothesized that the lambs in the current experiment were too young to deposit detectable amounts of lutein in the fat as detected in fattened lambs (Prache *et al*., 2003). Lambs grouped in Class 1 and 2, with low intake, presented similar contents in the liver and muscle but lower than the lambsin Class 3 and 4 (P<0.05). Similarly, the content of retinol in the liver (P<0.05), muscle and both fat tissues (P<0.01) increased with retinol intake. However, the contents only differed between Class 1 and Class 4 (P<0.05).

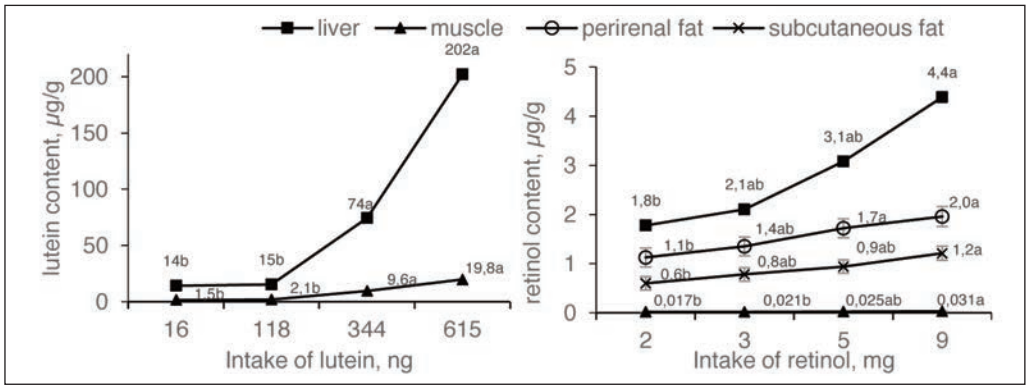

Fig. 1. Effect of the intake on the deposition of the analyte in tissues of the suckling lamb. Within a tissue, means with different letter differ at P<0.05.

The increase of α-tocopherol intakewas reflected in the liver (P<0.001), muscle (P<0.01), perirenal fat (P<0.05) and subcutaneous fat (P<0.01) (Fig. 2). Similarly, vitamin E supplementation of different forms in the diet increased α-tocopherol content in adipose tissue (Kasapidou *et al*., 2009). However, the increase in the intake of γ-tocopherol was onlyreflected in subcutaneous fat (P<0.05). The absence of a clear effect of the intake on the contents of γ-tocopherol could be related to a loss of γ-tocopherol apparently due to discrimination by the liver, although the absorption of α– and γ-tocopherol is similar (Debier and Larondelle, 2005). Then, it is more difficult to modify the content of γ-tocopherol than that of α-tocopherol through the diet.

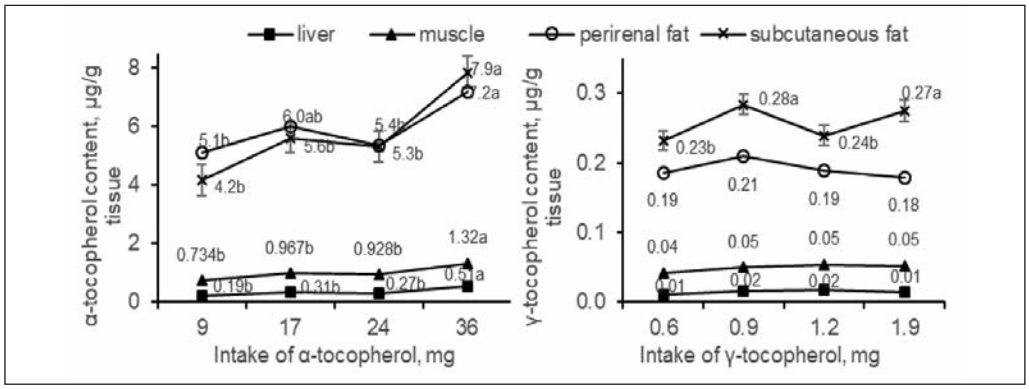

Fig. 2. Effect of α– and γ-tocopherol intake on the deposition of the analyte in tissues of the suckling lamb. Within a tissue, means with different letter differ at P<0.05.

IV – Conclusions

In conclusion, the contents of retinol, lutein and α-tocopherol in the tissues of the suckling lamb respond differently to the intake of the respective analytes. The contents of γ-tocopherol are difficult to modify with low intakes of the analyte.

Acknowledgments

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Preservation of microbiological and sensory quality of sheep meat using pomegranate bark extracts

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Abstract. Fresh meat is a sensitive and unstable product over time due to its composition and physicochemical characteristics (pH and aw). The length of storage time depends on temperature, atmospheric oxygen, endogenous enzymes, humidity, light and, above all, the microorganisms initially present. The challenge of preserving meat dates back to antiquity and has now intensified with the industrialization of meat products. Thus, in this work, we studied the conservation of meat by pomegranate bark extract to extend meat storage time, which may be a promising way to promote this coproduct of pomegranate in meat industry. We evaluated the effect of pomegranate bark extract on the growth of microorganisms naturally present in sheep meat. We carried out the microbial germ count by the decimal dilution method. We performed successive dilutions of the sample in sterile physiological water. Then, we evaluated total aerobic mesophilic flora (TAMF) and total coliforms (TC) The treated meat with three concentration of extracts (50-25-0.12 mg /ml) were stored at 4°C. Then, we monitored the physicochemical and microbiological modification during 12 days of conservation. The results show that the microbial kinetics of the strains were significantly affected by pomegranate bark extract especially with high concentration (C1 = 50 mg/ml). A significant increase in UFC (colony-forming unit) over time was observed in the untreated meat. In conclusion, pomegranate bark extract has a preservative effect against microbial alteration of raw sheep meat.

Keywords. Pomegranate bark – Sheep meat – Conservation – Microbial alteration.

Préservation de la qualité microbiologique et sensorielle de la viande de mouton par l'utilisation des extraits d'écorces de grenade

Résumé. *La viande fraîche est un produit sensible et instable dans le temps en raison de sa composition et de ses caractéristiques physico-chimiques (pH et aw). La durée de conservation dépend de la température, de l'oxygène atmosphérique, des enzymes endogènes, de l'humidité, de la lumière et, surtout, des micro-organismes présents au départ. Le défi de la conservation de la viande remonte à l'Antiquité et s'est intensifié avec l'industrialisation des produits carnés. Ainsi, dans ce travail, nous avons étudié la conservation de la viande par l'extrait d'écorce de grenade afin de prolonger la durée de conservation de la viande, ce qui pourrait être un moyen prometteur de promouvoir ce coproduit de grenade dans l'industrie de la viande. L'effet de l'extrait d'écorce de grenade sur la croissance de micro-organismes naturellement présents dans la viande de mouton a été évalué. Les caractéristiques des écorces de grenadier ainsi que la charge microbienne notamment, la flore mésophile aérobie totale (TAMF) et les coliformes totaux (CT) ont été évalués. La viande traitée avec trois concentrations d'extraits (50-25-0,12 mg / ml) a été stockée à 4 ° C. Le suivi des échantillons a été effectué pendant 12 jours de conservation. Les résultats montrent que l'extrait d'écorce de grenade a un effet important sur la cinétique microbienne des souches, en particulier à forte concentration (C1 = 50 mg / ml). Une augmentation significative de l'UFC (unité formant des colonies) au fil du temps est observée en l'absence de l'extrait. En conclusion, l'extrait d'écorce de grenade a un effet retardateur d'altération microbienne de la viande de mouton crue.*

Mots-clés. *Ecorce de grenade – Viande de mouton – Conservation – Altération microbienne.*

I – Introduction

Fresh meat is a highly perishable product due to its biological composition. Many interrelated factors influence the shelf life and freshness of meat such as holding temperature, atmospheric oxygen, endogenous enzymes, moisture, light and most importantly, microorganisms. With the increased demand for high quality, convenience, safety, fresh appearance and an extended shelf life in fresh meat products, alternative non-thermal preservation technologies such as natural biopreservatives are highly demanded.

Furthermore, several works carried out on pomegranate bark has proven its antimicrobial, antioxidant, anti-carcinogenic (Al-Saeed *et al*., 2015), antiseptic and antifungal activities (Kanoun, 2004). However, the exploitation of this antioxidant and antibacterial potential in the agri-food sector remains unknown and very limited. Thus, we have been interested in studying the conservation of meat by pomegranate bark extract to extend meat storage time, which may be a promising way to promote this coproduct in meat industry.

II – Materials and methods

The pomegranate fruit is the Sefri variety. This fruit was collected from the region of Ouled Abdellah of Beni Mellal. The barks were dried in an oven at 60°C for 24 hours. Subsequently, we crushed them with a food grinder. The particle size is less than 0.25 mm.

The preparation of the aqueous extract of pomegranate bark was carried out by the infusion method. Several concentrations were prepared from the powder obtained (50-25-0.12 mg /ml) in boiling water, macerated for 2 hours under stirring, the samples were then filtered (filter porosity: 0.22 µm) and the filtrates stored at 4°C.The chemical characteristics of bark powder extracts: pH, titratable acidity, ash content and soluble solidity rate as well as colour and total polyphenols.

The sheep meat is provided by Deroua Research Station of the national institute of agronomical research (INRA–CRRAT), located in Beni Mellal, Morocco. The ram is of the boujaâd breed. Slaughter took place with in Research station and the pieces used for the test were prepared from the thighs.

After cutting the carcass, we recovered the thigh muscles. The fat around the muscles was removed. The meat was cut into pieces of about 5 g (2x2 cm). Then, we treated the pieces of meat by immersion in three-concentrations prepared from extracts of pomegranate bark. The meat pieces were drained and putted in a sterile petri dish to be deposited at 4°C (Fig. 2). The colour, water retention capacity and microbiological monitoring were evaluated over time of storage.

The meat quality was monitored using the accelerated ageing method. It is a fast method based on the provocation of a severe deterioration of the product by using high temperatures. For this test, meat samples were stored at 4°C. The evolution of the total aerobic mesophilic flora (FMAT) and total coliforms (TC) was carried out during 12 days of conservation (at 0, 3, 6, 6, 9 and 12 days of storage).

The meat was cooked in 10 g pieces without the addition of salts and in the absence of oil. Twenty tasters had been invited to analyse the products and complete the sensory evaluation sheets of meat witness and those with a dose of pomegranate bark extract (12.5-25-50 mg /ml). The preference test and triangle test were assessed to evaluate the consumer acceptability.

The analyses of variance (ANOVA) were carried out by (Statistical Package for the Social Sciences). All analyses were performed at least in duplicate. The results were presented by the mean with its standard deviation. The differences were considered significant at $p < 0.05$.

Fig. 1. Carcass cutting in the INRA Béni Mellal abattoir.

Fig. 2. Meat treatment with the three concentrations of the extract.

III – Results and discussion

The main physicochemical characteristics of pomegranate bark powder and their values are detailed in Table 1.

Table 1. Chemical characteristics of pomegranate bark powder

Criteria		Values
Ph		4.68±0.02
Titratable acidity (g/ml)		2.04±0.25
TSS (Brix°) %		3.07±0.12
Ash content		10%
Colour	L	8.71±0.01
	a	1.70±0.04
	b	1.48±0.04
Total Polyphenols (g EAG/100g)		16.48±2.32

The pomegranate bark powder has a pH value of 4.68. These results are in agreement with those reported by Mediani and Guerhli (2015) who found 4.77. The value of the titratable acidity is 2.04 g/ml, which is slightly higher than that reported by Sidoummou in 2011 (1.59). Moreover, the Brix value of the powder is 3.07%. Color is among the physico-chemical parameters that influence the acceptability of the food product. It was measured by three wavelengths L, a and b; for our pomegranate bark powder, the value of L is 8.71.The red index a is 1.70. this value is lower than that (3.9) mentioned by Mediani and Guerhli (2015). Concerning the yellow index b, the value is 1.48. The total phenolic compounds value is 16.48 (g EAG/100 g MS); this result is close to that reported (21.7 g EAG/100 g MS) by Ben Nasr *et al*. (1996).

1. Evaluation of meat treatment with pomegranate bark extract

The carcass pH measured immediately after slaughter is 6.32, and after 24 h of slaughter it decreased to 5.88. This decrease in pH is related to the accumulation of lactic acid produced by the degradation of intramuscular glycogen.

The results of monitoring the water loss of meat treated with pomegranate bark extract are presented in Table 2.

Table 2. Effect of pomegranate bark powder extract on water retention at raw sheep meat during storage at 4°C for 12 days

	After slaughter	After 3 days	After 6 days	After 9 days	After 12 days
T	32.0±1.61	29.5±3.79	29.4±1.77	27.1±1.66	23.3±4.45
C1	–	31.4±2.91	30.8±4.18	29.2±1.5	19.9±5.97
C2	–	28.7±2.73	29.2±0.62	26.8±0.77	17.7±0.27
C3	–	27.4±0.94	27.7±4.11	25.6±1.11	16.4±3.43

T: Control without pomegranate bark extract; C1:25mg/ml; C2:12,5mg/ml; C3:6,25mg/ml.The values in the same column are significantly different ($p < 0.01$). The values of the same line are significantly different ($p < 0.01$). All results are expressed as an average ± Standard deviation. All results are averages of 3 replicates.

The average value of water loss is improved compared to the control samples. The decrease in water retention capacity is explained by the loss of myofibrillar structure caused by the attack of proteolytic enzymes. During this process, the structure at inside and between the myofibrils breaks, thus reducing the firmness of the meat. The cellular membrane becomes permeable and intracellular water moves through the extracellular fluid. Maturation itself does not change the water outlet of the myofibrils, but with time, the membrane structures disintegrate and water leaves the muscle cells much more easily, thus increasing the expressible juice (Honikel, 1989).

Table 3. Colour assessment of sheep meat during storage, treated by the different concentrations of the pomegranate extract

	After slaughter			After 3 days			After 6 days			After 9 days		
	L	a	b	L	a	b	L	a	b	L	a	b
T	31.24±0.26	60.20±0.26	27.37±1.21	33.79±1.95	71.18±2.39	54.48±1.72	28.89±0.40	68.70±0.91	40.91±0.95	20.63±0.15	48.59±0.87	20.83±0.27
C_1	–	–	–	31.13±0.69	69.69±1.99	45.90±2.05	30.41±0.45	70.37±0.73	44.66±1.06	28.95±0.08	66.75±0.19	31.36±0.12
C_2	–	–	–	38.17±1.15	77.56±1.51	62.13±2.82	27.80±0.27	63.60±0.78	37.64±0.66	31.63±0.07	70.97±0.05	34.76±0.13
C_3	–	–	–	38.65±0.51	76.71±0.28	62.09±1.39	27.62±0.25	61.75±0.64	36.18±0.54	34.05±0.71	73.39±0.80	45.04±0.27

T: Control without pomegranate bark extract; C1:25mg/ml; C2:12,5mg/ml; C3:6,25mg/ml.The values in the same column are significantly different ($p < 0.01$). The values of the same line are significantly different ($p < 0.01$). All results are expressed as an average± Standard deviation. All results are averages of 3 replicates.

Results show that clarity “L”, red index “a” and yellow index “b” of untreated meat were instable and decreases significantly after 9 days of storage at 4°C. However, these parameters increased remarkadly after 9 days of storage especially with concentration C3. Generally, treatment with all concentrations kept unchanged the color of meat even after 9 days of storage.

The microbiological monitoring (the total aerobic mesophilic flora and the total coliforms) of meat treated with pomegranate bark extracts are presented in Figures 3 and 4.

The microbial kinetics increase over the days for all treatment. However, the results indicate that the highest concentration (0.5 g / ml) acts as a delaying agent for bacterial contamination.

These results can be attributed to the fact that the pomegranate bark is rich in total polyphenols (16.48 g EAG / 100 g MS) that are characterized by their antimicrobial and antioxydant potential (Lairini *et al*., 2014). Also, Botsoglou *et al*. (2010) have shown that the addition of olive leaf extract to turkey meat improved microbiological quality of meat.

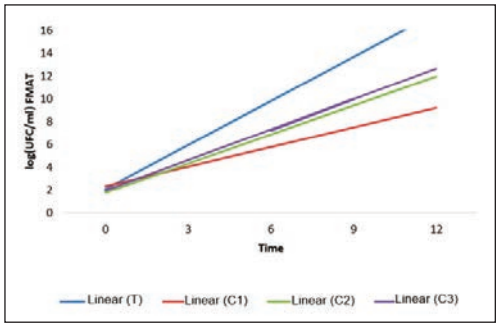

Fig. 3. Evolution of the number of FMAT total aerobic mesophilic flora expressed in log10 CFU/g, in sheep meat supplemented with different doses of pomegranate bark extract.

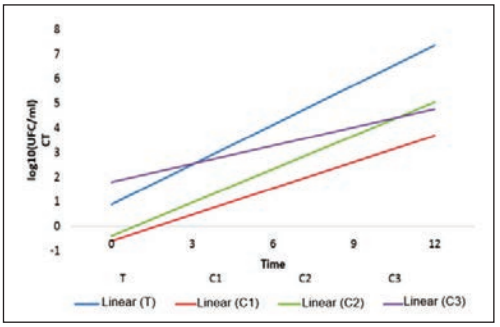

Fig. 4. Evolution of the number of total coliform CT in log10 CFU/g, in sheep meat supplemented with different doses of pomegranate bark extract.

2. Effect of pomegranate bark on the sensory properties of meat

Pomegranate bark has a significant effect on sensory quality. However, tasters accepted the new processed meat with pomegranate bark extract. In fact, they have appreciated the taste of the meat supplemented with pomegranate bark, compared to that of the control.

IV – Conclusions

In short, pomegranate fruit peel has a significant amount of total polyphenols that can be used as natural preservatives in several food applications through its antioxidant and inhibitory effect on harmful microorganisms. Our study highlighted the effect of incorporating the different concentrations of pomegranate bark extracts on microbiological and technological quality sheep meat. We showed that treating and processing meat with concentration of 25 mg/ml of pomegranate bark lead to better meat preservation in terms of water retention capacity, colour and essentially microbiological quality.

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Using stable isotope ratio to differentiate the Tunisian indigenous lamb grazing two different pasture types

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Abstract. The efficacy of isotope ratio mass spectrometry (IRMS) in tracing lamb production systems was investigated for four farming systems in the Tunisian North-West: Ain Draham and Fernana, characterized by woody pasture, and Amdoun and Joumine, characterized by herbaceous pasture. Mixed breed lambs aged 3.5–5 months were reared under semi-extensive and extensive systems. Samples of Longissimus dorsi muscle were taken from eight lambs for each farming system for stable IR assessment of the three main bio-elements (C, N, S) in the protein and fat fractions of lamb. Using partial least squares discriminate analysis (PLS-DA) the IR profiles of Tunisian lamb types allowed correct assignment of the training meat samples to pasture type. A broader scale pasture type discriminating lambs from the Amdoun (herbaceous pasture), the rest of north-west Tunisia appeared to be workable.

Keywords. Tunisian farming systems – Pasture type – Lamb Meat analysis – Isotope ratio.

Utilisation du ratio isotopique stable pour différencier l'agneau indigène tunisien pâturant en deux types de pâturage différents

Résumé. *L'efficacité de spectrométrie de masse à ratio isotopique (IRMS) dans le traçage du système de production d'agneau a été examinée pour quatre régions agricoles en Tunisie: Ain Draham (AD) et Fernana (F), caractérisés par le pâturage boisé (WP) et Amdoun (AM) et Joumine (J), caractérisés par le pâturage herbacé (HP). Des agneaux de différentes race, âgés de 3,5 à 5 mois ont été élevés dans des systèmes semi-extensifs et extensifs. Les échantillons de muscle Longissimus dorsi ont été prélevés sur huit agneaux pour chaque système d'exploitation afin d'obtenir une évaluation IR stable des trois principaux bioéléments (C, N, S) dans les fractions protéique et lipidiques de la viande. En utilisant l'analyse discriminante partielle des moindres carrés (PLS-DA), les profils IR des types d'agneau tunisiens ont permis d'affecter correctement les échantillons de viande provenant de pâturage. Le type de pâturage a distingué les agneaux d'Amdoun (pâturage herbacé), le reste du nord-ouest de la Tunisie semblait être réalisable.*

Mots-clés. *Système d'élevage tunisien – Type de pâturage – Analyse de la viande d'agneau – Ratio isotopique.*

I – Introduction

Meat quality appears to be strongly affected by the animal feeding system (Priolo *et al.*, 2001; Renerre, 1990). The farming system, namely the combination of the geographical, orographic, climatic, social, historical and cultural conditions in the reference area and production factors such as feeding regime, husbandry techniques, animal breed and category, gives rise to specific lamb types dis-

tinguished by particular meat characteristics that consumers may identify and appreciate (Sañudo *et al*., 2007). Authentication and objective food information are major demands from consumers (Monin, 1998). Stable isotope ratios provide an analytical tool for confirming meat origin, as there are region-specific patterns in the environmental isotopic ratios (Piasentier *et al*., 2003; Franke *et al*., 2005). Vegetation composition (C), feed type (C, N), crop production practices (N), and the sea (S) proximity (Moloney *et al*., 2009). Isotopes can therefore be used to detect dietary differences and origin. These objectives were achieved by developing classification models through the use of isotope ratio mass spectrometry (IRMS).

II – Materials and methods

1. Animals, diets and experimental design

The study was carried out at four sites in north-western Tunisia. The farming systems are characterized by different kinds of pasture, mountainous terrain covered with woody pasture (WP) and plains dominated by herbaceous pasture (HP). In the Ain Draham (AD) and Fernana (F) systems, pasture grazing takes place virtually throughout the year, with bushes and shrubs dominated by cork oak (*Quercus suber*), while the kermes oak (*Quercus coccifera*) covers relatively small areas. Lambs are given supplements of oak acorn, some commercial concentrates, barley and oat hay. The Amdoun (AM) and Joumine (J) sites are characterised by HP, comprising a herbaceous stratum dominated by *Gramineae*, on which the lambs graze with their dams; as a supplement to pasture, the flocks receive commercial or farm concentrate, green barley, oats, hay and wheat straw.

2. Slaughter and sampling procedures

The lambs were transported to a commercial slaughterhouse located 120 km from the farms and then slaughtered after an overnight period without feed but with free access to water. All the procedures employed in this study (transport and slaughtering) meet ethical guidelines and adhere to Tunisian legal requirements in accordance with Law no. 2005-95 (18 October 2005).

The *Longissimus dorsi* (thoracis + lumborum) (LD) muscles of both sides of the lamb carcasses were separated for meat quality analysis. Two equivalent samples from the left and right muscles from each lamb were frozen at –20°C for IRMS analysis.

3. Sample preparation and isotope analysis

The LD meat samples were minced and freeze-dried in a lyophilizer (freeze-drier) then homogenized with a suitable grinder and freeze-dried again. The resulting dry powder was fractionated into crude fat (Fat), by extraction with petroleum ether for 6 h in a Soxhlet apparatus, and defatted dry matter (Protein), essentially protein. Afterwards the protein and fat fractions were stored in an appropriate container until measurement. Measurement of the $^{13}C/^{12}C$, $^{15}N/^{14}N$, ratios of protein and fat fractions was carried out as described by Perini *et al*. (2009). For $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios we used an Isotope Ratio Mass Spectrometer (DELTA V, Thermo Scientific, Germany) following total combustion in an elemental analyser (EA Flash 1112, Thermo Scientific). $^{34}S/^{32}S$ was determined using IRMS (Vario Isotope Cube, Elementar Analysensysteme GmbH, Germany) The values were expressed in δ‰ against international standards, calculated against working in-house standards and calibrated against international reference materials, as reported by the same authors. For measurement of the $^{34}S/^{32}S$ ratios, we used an elemental analyser (EA Flash 1112 Thermo Finnigan, Bremen, Germany) connected to an isotope ratio mass spectrometer (Delta plus XP mass spectrometer, Thermo Finnigan). The protein sample (2.5 mg) was burned at 1000 °C in a quartz tube filled from the bottom with quartz wool (2 cm), elemental copper (14 cm), copper

oxide (5 cm) and quartz wool (1 cm). The water was removed using a glass trap filled with Mg $(ClO_4)_2$. The isotopic values were calculated against international reference materials: IAEA-SO-5 ($\delta^{34}S$ = +0.5‰) and NBS 127 ($\delta^{34}S$ = +20.3‰), through the creation of a linear equation.

4. Statistical analysis

The four farming systems located in four areas of Northwest Tunisia were first compared by univariate analysis. Particularly, the effect of lamb farming system on each individual stable isotope ratio in meat was investigated using ANOVA, followed by Fishers Least Significant Difference (LSD)

III – Results and discussion

The IR profiles of lamb produced at the four locations in north-west Tunisia are shown in Table 1. All the IRs were significantly influenced by the geographical origin of the meat. However, only in the case of $\delta^{34}S_{Protein}$ did the pasture type significantly affect the IR value (9.7‰ vs. 6.9‰ for WP and HP respectively; p<0.001). This means that IR variability between sites is higher than that between pasture types.

A clear example of this can be seen in the $\delta^{13}C$ values of both protein and the more depleted fat fractions (DeNiro and Epstein, 1977), which did not differ for the pasture systems. $\delta^{13}C$ values instead showed statistically significant differences between sites. Indeed, the maximum $\delta^{13}C$ values for protein and fat fractions, recorded in Fernana and Amdoun lamb meat (-25.1‰ and –31.3‰ respectively), only differed by 1.1-1.4‰ from the minimum $\delta^{13}C$ values that were respectively observed in Joumine (-26.2‰ for protein) and Ain Draham (-32.5‰ for fat). These differences are probably linked to the forage/concentrate ratio in the lamb diet and the acorn intake (González-Martin*et al*., 2001; Perini *et al*., 2013). As expected, the $\delta^{13}C$ values were low in comparison with those observed by Perini *et al*. (2009) in Italian lamb types, because of the absence of C4 plants in their diet (Camin *et al*., 2007).

Meat from Amdoun, produced from lambs grazing on herbaceous pasture with their dams, was characterised by the highest $\delta^{15}N_{Protein}$. The WP systems showed intermediate values. The differences between Amdoun and Joumine, characterised by a similar humid climate and HP, may result from differences in agricultural practices, particularly the organic fertilisation largely used in Amdoun, which increases the $\delta^{15}N$ of forage (Laursen *et al*., 2013). Moreover, in comparison with AM-HP (Table 1), J-HP breeders feed their flocks with significant amounts of legumes, namely clover, which is known to have a low $\delta^{15}N$ level in its nitrogen, compounds (Laursen *et al*., 2013). Furthermore, they usually wean their lambs earlier than AM lambs, which are kept with the ewes until slaughter, and higher $\delta^{15}N$ is expected in suckling animals (Perini *et al*., 2009). The higher level of deuterium in the fat fraction of J-HP meat was in line with the rougher diet of J-HP than AM-HP sheep that receive higher amounts of concentrates and barley (Table 1).

The $\delta^{34}S$ examined, sulphur provided the clearest lamb type discrimination. Similar results were obtained in a study carried out on Italian lamb types (Perini *et al*., 2009). The basis of Italian-lamb-type variability was not feed dependent. The upper end of the $\delta^{34}S_{Protein}$ range was represented by two lamb types (9.5‰ and 9.2‰), reared on the Mediterranean islands of Sicily and Sardinia at 5 and 10 km from the sea respectively. The two WP systems in Tunisia, Fernana and Ain Draham in particular, are also the closest to the sea. Thus, the high $\delta^{34}S$ content would seem to be a “coastal” signal, resulting from the influence of so-called sea-spray. Sea-spray sulphate is deposited as an aerosol over pasture and crops, in decreasing amounts with increasing distance from the sea.

Table 1. Isotopic ratio values (‰) of protein and fat of lamb meat from four farming systems located in four areas of Northwest Tunisia, Ain Draham (AD) and Fernana (F) characterized by woody pasture (WP), Amdoun (AM) and Joumine (J) characterized by herbaceous pasture (HP)

	AD-WP	F-WP	J-HP	AM-HP	*p*	SEM
$\delta^{13}C_{Protein}$	-26.1^{c}	-25.1^{a}	-26.2^{c}	-25.6^{b}	.000	.08
$\delta^{15}N_{Protein}$	7.1^{b}	6.3^{bc}	5.6^{c}	10.2^{a}	.000	.15
$\delta^{34}S_{Protein}$	10.0^{a}	9.4^{a}	7.5^{b}	6.3^{b}	.000	.21
$\delta^{13}C_{Fat}$	-32.5^{b}	-31.3^{a}	-32.3^{b}	-31.1^{a}	.000	.10

^{a,b,c}: $p<0.05$.

IV – Conclusions

Initial application of IRMS to trace farming systems in north-west Tunisia provided promising results for both large-scale discrimination of north-west Tunisia as an overall lamb-producing geographical region and small-scale classification of individual regional farming systems. In particular, it appeared to be reliable in distinguishing lamb produced in the Amdoun area, characterised by a humid climate, extensive use of organic manure to fertilise forage crops and fallows grazed by flocks comprising lambs suckled by their dams until slaughtering, on the basis of the IR profile. The use of meat from other Tunisian production systems, such as naturally reared prairie or feedlot lambs, may be interesting to discriminate the mountainous meat production system.

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Improving milk antioxidant activity and nutritional composition through the incorporation of *Argania spinosa* (L.) by-products in goat's diet

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Abstract. Many studies reported that beneficial bio molecules compounds have been identified from various parts of the *Argania spinosa* (L.) Skeels and can play an important role in fighting diseases. Certainly, Morocco includes the most important rate of production, but the different by-products of this tree are not valorised. In this present study, we investigate the effect of the incorporation of the Argane tree's by-product in goat's diet, on the antioxidant activity, the microbiological quality, the physicochemical and mineral composition of Alpine goat milk collected from Essaouira, Morocco. The preliminary results of this study revealed a remarkable improvement in several of the analysed parameters, especially the fat content with an increase of 51.21%, which remains the most noteworthy. Microbiological analysis showed that the mean mesophilic aerobic flora count for goats consuming the Argane by-product diet (AD) was $1.38.10^7 \pm 2.67.10^7$ Cfu.mL^{-1} comparing to $2.96.10^7 \pm 5.42.10^7$ Cfu.mL^{-1} for those consuming the Control Diet (CD). The total phenolic content of milk collected from goats consuming AD varied from 17.29 ± 0.61 to 22.65 ± 1.15 mg GAE/g of DM, while that the total phenolic content of milk collected from goats consuming CD varied from 10.74 ± 0.39 to 12.46 ± 0.33 mg GAE/g of DM. Furthermore, mineral analysis demonstrated that AD milk samples are rich in potassium, magnesium and other minerals with many health benefits.

Keywords. Goat milk – *Argania Spinosa* – By-product – Antioxidant activity.

Amélioration de l'activité antioxydante et la composition nutritionnelle du lait de chèvre par l'incorporation des co-produits d'*Argania Spinosa *dans la ration des chèvres

Résumé. *De nombreuses études ont montré que des composés de biomolécules bénéfiques avaient été identifiées dans différentes parties de l'*Argania spinosa *(L.) Skeels et qu'elles pouvaient jouer un rôle important dans la lutte contre les maladies. Certes, le Maroc comprend le taux de production le plus important, mais les expériences de culture dans de nombreux pays, sont prometteuses, et les différents co-produits de cet arbre ne sont pas valorisés. Dans la présente étude, nous étudions l'effet de l'incorporation des co-produits de l'arganier dans l'alimentation des chèvres, sur l'activité antioxydante, la qualité microbiologique, la composition physicochimique et minérale du lait de chèvre alpines collecté à Essaouira - Maroc. Les résultats préliminaires de cette étude ont révélé une amélioration remarquable de plusieurs paramètres analysés, notamment le taux de matière grasse avec une augmentation de 51,21%, qui reste le plus remarquable. Les analyses microbiologiques ont montré que la valeur moyenne de la flore aérobie mésophile totale chez les chèvres consommant le régime contenant les co-produits d'Argane (AD) était de 1,38.107 ± 2,67.107 Cfu.mL^{-1}, comparé à 2,96.107 ± 5.42.107 Cfu.mL^{-1} pour le lait du Régime contrôle (CD). La teneur en composés phénoliques totaux du lait des chèvres consommant la ration alimentaire à base des co-produits de l'arganier variait de 17,29 ± 0,61 à 22,65 ± 1,15 mg GAE / g de matière sèche, tandis que la teneur en composés phénoliques totales du lait des chèvres consommant la ration contrôle variait de 10.74 ± 0.39 à 12.46 ± 0.33 mg GAE/g de matière sèche. En outre, l'analyse des minéraux a montré que les échantillons de lait issu des chèvres consommant le régime AD étaient riches en potassium, magnésium et autres minéraux offrant de nombreux avantages pour la santé.*

Mots-clés. *Lait de chèvre – Co-produits –* Argania spinosa *– Activité antioxydante.*

I – Introduction

In Morocco, goat population is estimated at 5.3 million head, occupying the 2nd place in local farming (Zaaraoui *et al*., 2016), and the 13th place on a world scale (El Moutchou *et al*., 2013).These goats are adaptable to the climatic conditions and ensure the production of several products such as meat, milk and skins (Badis *et al*., 2004). Goat milk represents a food of high nutritional value, due to its composition and recognized benefits for human well-being (Lakram *et al.,* 2019), Therefore, goat milk is considered to possess a high antioxidant potential that resists to oxidative stress which is an important characteristic of numerous cardiovascular related diseases (Alyaqoubi *et al*., 2014). However, livestock production in Morocco suffers from serious feeding problems, during the limited forage availability period, due to shortage, low protein content resources and lack of development of alternative feed resources (Mercha *et al.,* 2019). Among these unconventional alternative resources is the Argan press oil cake that represent an excellent nutrient source with 43.1 % of protein and 21.3% of crude fiber (Mercha *et al.,* 2019). It is therefore an efficient alterative feed resource to improve production and nutritional value of goat milk and its integration in human diets, with health promoting components. This work aims to study the effect of the incorporation of argan by-products in dairy goat on antioxidant activity and nutritional composition of goat milk produced in Essaouira region.

II – Material and methods

An experiment was carried out in the region of Ounagha (Essaouira, in the region of Marrakech, Safi), during. a period of 90 days, on two groups of twelve (12) alpine goats , divided randomly, each with an average age of 2 years. The first group of goats consumed a diet prepared basically from by-products of the Argane tree (press cake (25%) and pulp (20%) as dry matter basis (DM)), while the second fed a diet without Argane by-products (control group). Both groups were receiving 1.5 kg of prepared diets twice a day and a fifteen (15) days adaptation period was respected.

The tested diet is composed of Argane press cake , Argane pulp , wheat bran , barely , chopped straw and a complex of minerals and vitamins (Table 1), Dry matter (DM), ash, ether extract (EE), crude fiber (CF), and crude protein (CP) were determined according to the Association of Official Analytical Chemists methods (AOAC , 2011).The animals were fed normally, and the water was available all time. The nutritional balance was established according to the energy and protein requirements of ewes in the lactation phase following the INRA system.

Table 1. Composition of the experimental diets

	Argane Diet (AD)	Control Diet (CD)
Ingredients (g/100 g of fresh matter)		
Argane press cake	250	0
Argane pulp	200	0
Ground straw	100	170
Wheat bran	250	180
Barley grain	180	200
Minerals and vitamins	20	0
Commercial feed	0	250
Lucerne	0	200
Chemical composition, % (DM basis)		
Crude protein	16.4	11.5
Dry matter	87.2	78.7
Ash	6.56	7.37
Crudefiber	12.9	10.30
Ether extract	3.50	2.12

Raw goat milk samples were collected twice at morning and evening periods in sterile bottles and maintained at 4°C condition during their transport to the food technology laboratory of regional center of agronomic research- INRA, rabat. The pH of the milk samples was determined electrometrically with a pH-meter (Micro pH 2002, Crison, Barcelona, Spain). The physicochemical parameters (fat, solids-non-fat, density, protein, lactose, salts and freezing point were measured using a Lactoscan Milk Analyzer calibrated for goat milk.Thus, a microbiological quality follow-up was provided on the day of the collection of themilk samples, for a count of contaminating microorganisms following the International Dairy Federation protocol (IDF.1987), to be able to evaluate the effect of the incorporation of the prepared food diet on the development rate of bacterial strains.

The antioxidant capacity of each sample through total phenolic content TPC was determined according to (Shori *et al.,* 2011) with minor modification. 200 µl of fresh goat milk extract was added to 1 mL diluted Folin – Ciocalteu reagent and 800 µl of Sodium carbonate solution. After 2 hours incubation, the absorbance was measured at 765 nm wavelength.

Trace elements of milk, including iron, copper, manganese, and zinc, were analyzed by atomic absorption spectrometryin a flame air-acetylene. The measured absorption was done at a specific wavelength of 248.3 nm.

All analysis were carried out in triplicate, data was statistically treated using variance analysis (ANOVA), results are shown as mean, and differences among means were ranked using Duncan's New Multiple Range Test. The significance level was 5%.

III – Results and discussion

1. Milk physicochemical and microbiological quality

Milk quality and quantity are mainly affected by several factors including breed, stage of lactation, milking system and sheep feeding (Mouhaddach *et al*., 2016). Physicochemical results of analyzed milk samples collected during the trial are presented in Table 2. The incorporation of the Argane by-product's diet offers a milk with more fat (4.20 % compared to 2.92% for the control group), more protein content (3.27 % compared to 2.56 % for the control group). For all criteria, the composition of milk from goats fed by the Argane diet exceeded those from the control animals. Our research shows that the number of microbes of technological interest is very high, and this presents an economic and qualitative advantage for industrialists (Lakram *et al*., 2019).

Table 2. Physicochemical content of goat milk from Argane and control diets

	Argane Diet	Control Diet	SEM	*p*
Density, g/cm^3	1.028^a	1.019^b	0.09	<0.001
Fat, %	4.20^a	2.92^b	0.05	<0.001
pH	6.67^a	6.61^b	0.299	<0.001
Protein, %	3.27^a	2.56^b	0.20	<0.001
Lactose, %	4.16^a	4.04^b	0.72	<0.001

Microbial quality is important for milk preservation and its transformation. The results obtained by an enumeration of the different microbial flora of raw goat milk samples are summarized in Table 3.

Overall, the microbiota of raw milk can be influenced by several factors, including animal feeding, seasonal variation, geographical farm location and milking procedures. Since all the factors were stabilized, our results showed that the feeding factor had an effect on goat milk flora. Microbial counts in the AD were lower than those of CD, likely due to the presence of antimicrobial factors in the Argane diet.

Table 3. Microbiological analysis (mean)in function of diet type

	Argane Diet	Control Diet	SEM	*p*
Total aerobic flora	$1.1{\cdot}10^{4\ b}$	$1.1{\cdot}10^{5\ a}$	0.10	<0.001
Total coliform	$3.1{\cdot}10^{4\ b}$	$1.1{\cdot}10^{5\ a}$	0.74	<0.001
Fecal coliform	$2.5{\cdot}10^{5\ b}$	$4.2{\cdot}10^{5\ a}$	0.26	<0.001
Staphylococcus	$3.8{\cdot}10^{1\ b}$	$5.7{\cdot}10^{1\ a}$	0.95	<0.001
Yeasts and molds	$2.8{\cdot}10^{2\ b}$	$1.6.10^{4\ a}$	0.47	<0.001

2. Total phenolic and mineral content

Many studies reported that beneficial bio molecules compounds have been identified from various parts of *Argania spinosa*'s (L.) Skeels and can play an important role in fighting diseases and could be used in pharmaceutical and personal care products (Elbabili *el al.*, 2010). Figure 1 illustrates phenolic contents of both diets.

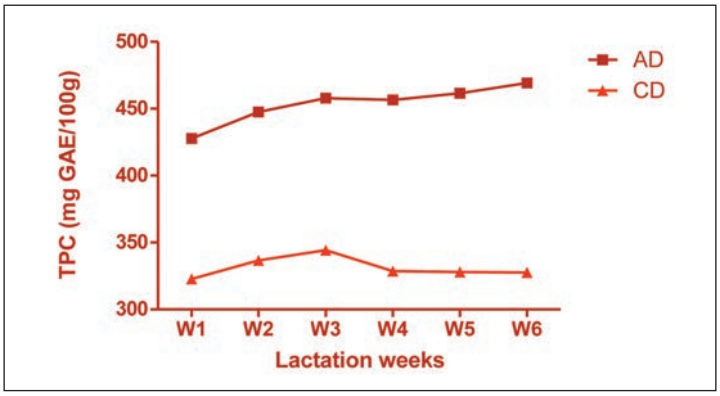

Fig. 1. Phenolics contents of goat milk (mg GAE/100 g DM) as related to diet type and lactation stage. Data are presented as mean ± SEM, n = 3 experiments, p values; *p < 0.05, **p < 0.01, ***p < 0.001. AD: milk collected from goat fed by diet including Argane by- products; CD: milk received from goat fed by local diet.

Among the diets offered, the experimental diet based on Argane byproducts supplied the largest amount of total phenolic compounds with averages of 447.28 ± 1.43 mg GAE/g for AD group, and 344.78 ± 1.26 mg GAE/g for CD group. These results are in accordance with those reported by (Alyaqoubi *et al*., 2014).

Following previous studies, milk and dairy products supply all essential mineral elements needed for newborn development and growth. In this work animal feed and lactation week had a significant effect (P < 0.001) on goat milk trace elements (Cu, Zn, Mg and Fe). Milk iron is naturally low. In our case, the average values of milk iron were 0.09, and 0.05 mg/100 g for the AD, and CD diets, respectively. The iron concentration reported in the literature for goat milk was 0.07 mg/100 g (Park *et al.,* 2007).

IV – Conclusion

The present study revealed that the inclusion of the Argane by-products in goat's diet improved the global quality as well as the antioxidant potential of collected milk, in addition to its mineral composition. Therefore Argane by-products must be considerated as a promising alternative for dry season feeding systems and, thereby undoubtedly reduce the pressure on silvopastoral resources and production costs and consequently improve the income of livestock farmers in dry areas. However, further testing is required on secondary metabolites production in collected milk.

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Impact of propolis as a natural antibiotic on diet digestibility, purine derivatives, methane emission and blood constitutes of late pregnant ewes

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Abstract. Antibiotic are widely used in ruminant nutrition as feed additives to improve growth energy, protein utilization and decrease methane (CH_4) emissions. However, there is a controversy about the use of such additives because of the risk of transferring residues into meat and milk and development of resistant strains of bacteria. These concerns have promoted the search for alternative natural feed additives, such as propolis. Eighteen ewes were individually allotted to indoor pens to study the impact of propolis as a natural antibiotic on diet digestibility, purine derivatives, CH_4 emissions and blood constitutes of late pregnant Santa Inês ewes. The study lasted for 43 day and ewes were assigned to a randomized complete block design with 9 blocks and 2 dietary treatments as follows: Control (CTL) without propolis administration and propolis (BRP) received 3 g red propolis extract /ewe/day. Intake of N and body N retention increased ($p < 0.05$) for BRP supplementation than CTL expressed as g / animal / day. The administration of BRP increased ($P < 0.05$) urinary allantoin compared to the CTL. BRP supplementation increased ($P < 0.05$) OM and CP digestibility compared to the CTL. Additionally BRP decreased ($P < 0.05$) CH_4 emission expressed as L/day or L/kg for (OMI and DOM) when compared to CTL group. Propolis increased ($P < 0.05$) all hematological parameters moreover the same pattern was observed for the biochemical parameters too. Propolis supplementation resulted in decrease ($P < 0.05$) cortisol, T_3 and T_4 compared to CTL. Propolis represents a promising natural antibiotic with profit biological and environmental effects.

Keywords. Antibiotic – Digestibility – Propolis – Methane – Purine derivatives.

Impact du propolis, un antibiotique naturel sur la digestibilité de la ration, les dérivés des purines, les émissions de méthane et les constituants du sang chez les brebis enfin de gestation

Résumé. *Les antibiotiques sont largement utilisés comme additifs alimentaires dans la nutrition des ruminants pour améliorer l'énergie de croissance, l'utilisation des protéines et pour réduire les émissions de méthane (CH_4). Cependant, l'utilisation de tels additifs pourrait être à l'origine du transfert de résidus dans la viande et le lait et du développement de souches bactériennes résistantes. Ces préoccupations ont favorisé la recherche sur les additifs naturels dans l'alimentation animale, tels que la propolis. Dix-huit brebis ont été individuellement logées dans des enclos pour étudier l'impact de la propolis en tant qu'antibiotique naturel sur la digestibilité de la ration, les dérivés des purines, les émissions de CH_4 et les constituants du sang chez les brebis de race Santa Inês en fin de gestation. L'étude a duré 43 jours et les brebis ont été affectées à deux groupes: le groupe témoin (CTL n=9) et celui qui recevait 3 g d'extrait de propolis rouge/ brebis / jour (BRP n=9). L'apport en azote et la rétention d'azote dans le corps ont augmenté ($p < 0,05$) pour la supplémentation en BRP par rapport aux CTL exprimés en g par animal et par jour. L'administration de BRP a augmenté ($P < 0,05$) l'allantoïne urinaire par rapport à celui du CTL. La supplémentation en BRP a augmenté ($P < 0,05$) la digestibilité de la matière organique et celle des matières azotées de la ration par comparaison au régime témoin (CTL). De plus, les BRP ont diminué ($P < 0,05$) les émissions de CH_4 exprimées en L / jour ou en L / kg pour (Quantité Ingérée de MO (MOI) et quantité de MO ingérée digestible (MOD)) par rapport au groupe CTL. La propolis a augmenté ($p < 0,05$) tous les paramètres hématologiques et le même schéma a été aussi observé pour les paramètres biochimiques. La supplémentation en propolis a entraîné une diminution ($P < 0,05$) du cortisol, des T_3 et T_4 par rapport aux CTL. La propolis est un antibiotique naturel prometteur ayant des effets biologiques et environnementaux bénéfiques.*

Mots-clés. *Antibiotique – Digestibilité – Propolis – Méthane – Dérivés de la purine.*

I – Introduction

Antibiotic growth promoters are widely used in ruminant nutrition as feed additives to improve energy and protein utilization and decrease methane (CH_4) emissions from ruminants (Wischer *et al*., 2013). However, there is a debate about the use of antibiotics in animal diets because of the risk of transferring residues into meat and milk and promoting the development of resistant strains of bacteria. These concerns have promoted the search for alternative natural feed additives, such as propolis (Morsy *et al*., 2013; Morsy 2015). Propolis is known to be active against (gram positive) bacteria, viruses, fungi, oxidants, inflammation, tumors, and parasites, and it may act as an immunomodulator (Alencar *et al*., 2007; de Aguiar *et al*., 2013; Morsy *et al*., 2015). There are many studies that confirmed the suitability of propolis as an effective feed additive for ruminants. Zawadzki *et al*. (2011) concluded that propolis supplementation, improved feed efficiency and body weight gain in feedlot-finished bulls. Ítavo *et al*. (2011) reported similar findings in growth performance of feedlot lambs. Brazilian red propolis was beneficial for ewe's health during the flushing period (Morsy*et al*., 2013). *In vitro*, propolis was effective in decreasing the formation of ammonia in the rumen (Oeztuerk *et al*., 2010) and inhibited hyperammonia-producing species of bacteria (de Aguiar *et al*., 2013). The most characteristic of propolis compared to the dietary antibiotic that propolis can decrease the CH_4 emission while improve the ruminal fermentation and nutrient degradability (Morsy *et al*., 2015). However, little information on the effect of propolis on the microbial protein synthesis is available. Thus, the hypotheses of the present study were that propolis as a natural antibiotic can improve the feed digestibility and enhance the microbial protein synthesis, while decreasing CH_4 emission during the critical period of late pregnant ewes. The objective of the present study was to investigate the impact of propolis on diet digestibility, purine derivatives, CH_4 emission and blood constituents of late pregnant ewes.

II – Materials and methods

1. Animals

This study was conducted in Centre for Nuclear Energy in Agriculture (CENA, USP) Piracicaba, Brazil.All animals were always treated in accordance to the Internal Commission for Environmental Ethics in Experimentation with Animals of CENA/USP (approval no. CIEEA/CENA 001/2011). Eighteen late pregnant Santa Inês ewes 52.5±2.50 kg body weight were individually allotted to indoor pens. The study lasted for 43 d and consisted of 14 d for adaptation and 29 d for data collection. Ewes were assigned to a randomized complete block design with 9 blocks and 2 dietary treatments. Control (CTL) without propolis administration and propolis (BRP) that received 3 g red propolis extract /ewe/day in the morning before access to diet for 21 days. Ewes were fed twice a day total mixed ration and formulated to meet NRC (2007). Total mixed ration is composed of (on DM basis) 50% tifton hay, 32.7% ground corn, 15.0% soybean meal, 1.0% limestone, and 1.3% mineral premix. The chemical composition of this ration includes (on DM basis); 92.4% DM, 13.1% CP, 2.0% EE, 4.3% ash, 71.8% NDF, and 34.3% ADF). Quantity of feed offered to animals was calculated according to previous daily DMI and adjustments were made when needed so that refused feed did not exceed 10% of the daily intake. Individual feed refusals were daily weighed to determine DMI.

2. Sampling and analysis

Feeds were sampled weekly throughout the trial and frozen at -20°C for further analyses. On the 7-day collection periods, the sheep were kept in metabolic cages, where complete individual daily collection of feed refusals, faeces and urine was performed to measure nutrient digestibility and N balance. Urine samples were analysed for N and for purine derivatives (i.e. allantoin, uric acid and creatinine) according to International Atomic Energy Agency (1997) by high performance liquid

chromatography (HPLC). The amount of microbial purines absorbed from the small intestine (PDa) was calculated according to Chen and Gomes (1992). At the end of the digestibility trial, animals were individually kept for two consecutive days in respiratory chambers for CH_4 determination as described by Abdalla *et al*. (2012). The CH_4 concentration was then determined on a gas chromatograph (GC) (Model 2014, Shimadzu, Tokyo, Japan) equipped with a Shincarbon ST 100/120 micropacked column (1.5875 mm OD,

1.0 mm ID, 1 m length; Ref. no 19809; Restek, Bellefonte, PA, USA). Blood samples (5 mL) were collected every week throughout experimental period before morning feeding. Samples were collected from the jugular vein using evacuated K2 EDTA tubes (Becton Dickinson & Co., Franklin Lakes, NJ) for hematological analyses and evacuated tubes without anticoagulant agents (Becton Dickinson & Co.) for biochemical analyses and hormones.

Blood serum concentrations of biochemical were determined by colorimetric kits using a commercial Labtest (Diagnóstica S.A®. Lagoa Santa, MG, Brazil). While hormones were analysed, by using radioimmunoassay (RIA) a commercial Siemens kit (Siemens Medical Solution Diagnostic, USA) using automatic Gama counter model (Wizard 2, Perkin Elmer, Dowens Grove, IL.USA). Data were analysed by analysis of variance using PROC MIXED procedure of SAS (2002).

III – Results and discussion

The effect of BRP supplementation on apparent diet digestibility and CH_4 emission are presented in (Table 1). Brazilian red propolis supplementation increased ($P < 0.05$) OM and CP digestibility compared with the control. Additionally BRP decreased ($P < 0.05$) CH_4 emission expressed as L/day or L/kg for (OMI and DOM) when compared to the control group. Such finding is in line with that reported by Morsy *et al*. (2015), who demonstrated that BRP extracts promoted the ruminal degradation of nutrients, as can be seen from the increase in the truly degraded OM and decreasing CH_4 emission by increasing short chain fatty acids and the decrease in the protozoal count *in vitro.* Propolis can not only reduce CH_4 production but also enhance the ruminal efficiency of dietary nutrient use. It could be concluded from the previous studies that propolis, despite of its color or type can indirectly affect methane formation by their anti-protozoal effect (Soltan *et al*., 2014).

Table 1. Effect of brazilian red propolis supplementation on feed intake, apparent diet digestibility and methane (CH_4) emission of ewes

Parameters	Treatments		s.e.m	Pr > F
	Control	Propolis		
Daily dry matter intake [g/sheep]	1108	1229	55.3	0.279
Diet digestibility [%]				
Dry matter (DM)	76.73	78.78	1.28	0.432
Organic matter (OM)	78.31^b	81.46^a	0.70	0.022
Crude protein (CP)	78.81^b	84.15^a	1.25	0.029
Neutral detergent fibre (NDF)	70.84	73.19	2.08	0.580
Acid detergent fibre (ADF)	49.13	73.19	2.83	0.650
Methane				
L/day	25.21^a	22.63^b	0.66	0.047
L/kg organic matter intake (OMI)	25.01^a	22.72^b	0.52	0.023
L/kg digestible organic matter (DOM)	32.38^a	28.10^b	0.97	0.024

^{a,b}Means within a row without a common superscript letter differ significantly ($p < 0.05$).

Intake of nitrogen ($p < 0.05$) and body N retention ($p < 0.05$) expressed as g/animal/day were higher with BRP supplementation compared with the control diet (Table 2). Xanthine and hypoxanthine were not detected in urine while total purine derivatives (PD) tended to increase. The administration of BRP increased ($p < 0.05$) urinary allantoin derivative excretion compared to the control. Propolis was able to increase DMI, which reflected an increasing N intake. The increasing N body retention approved the ability of enhancing the ruminal degradation of nutrients by propolis, as reflected by the increase of the truly degraded OM and by the transfer of N to milk or meat production (Morsy *et al*., 2015). Microbial protein synthesis can be indicated by an increase in various indicators like the partitioning factor, the urinary PD excretion and the body N retention (Soltan *et al*., 2013). So the observed increase in body N retention, and the tendency of total PD and allantoin (which account for the major proportion in purine derivatives) excretion reveal increasing microbial protein synthesis with the propolis supplementation.

Table 2. Effect of brazilian red propolis supplementation on nitrogen balance and urinary purine derivatives excretion of ewes

Parameters	Treatments		s.e.m	Pr > F
	Control	Propolis		
Nitrogen balance				
Intake [g/d]	37.0[b]	40.7[a]	0.86	0.032
Faecal excretion [g/d]	6.88	7.13	0.47	0.798
Urinary excretion [g/d]	7.96	6.59	0.67	0.317
Body retention [g/d]	19.5[b]	22.9[a]	0.71	0.017
N retained [g/g N intake]	0.52	0.64	0.03	0.073
Daily urinary excretion of purine derivatives (PD)				
Allantoin [mmol/animal]	8.49[b]	9.45[a]	0.25	0.052
Uric acid [mmol/animal]	2.56	2.24	0.26	0.551
Creatinin [mmol/animal]	4.47	3.75	0.54	0.516
Total PD [mmol/animal]	10.73	11.82	0.32	0.095

[a,b]Means within a row without a common superscript letter differ significantly ($p < 0.05$).

Table 3. Effect of brazilian red propolis supplementation on hematological, biochemical parameters and hormones of ewes

Parameters	Treatments		s.e.m	Pr > F
	Control	Propolis		
Hematological parameters				
Erythrocyte (RBC 106/ml)	10.96[b]	12.14[a]	0.30	0.056
Total leukocyte (WBC 103/ml)	11.03[b]	13.36[a]	0.52	0.007
Hemoglobin (Hb g/dl)	10.15[b]	11.62[a]	0.22	0.007
Packed cell volume (PCV %)	32. 53[b]	34.61[a]	0.51	0.040
Biochemical parameters				
Total protein (TP g/dl)	7.31[b]	8.95[a]	0.11	0.001
Albumin (Alb g/dl)	2.83	2.74	0.03	0.227
Globulin (Glo g/dl)	4.48[b]	5.22[a]	0.12	0.001
Glucose (Glu mg/dl)	45.86[b]	54.07[a]	1.06	0.050
Hormones				
Cortisol (Cor µg/dL)	1.98[a]	1.16[b]	0.140	0.002
Triiodothyronin (T3 µg/dL)	0.70[a]	0.56[b]	0.027	0.006
Thyroxine (T4 µg/dL)	7.81[a]	6.31[b]	0.335	0.022

[a,b]Means within a row without a common superscript letter differ significantly ($p < 0.05$).

The effect of BRP on hematological, biochemical parameters and hormones are presented in Table 3. Brazilian red propolis resulted in an increase (P<0.05) of all hematological parameters compared with control, moreover the same pattern was observed for some serum biochemical parameters such as total protein, globulin and glucose. Propolis supplementation resulted in a decrease (P<0.05) of cortisol, Triiodothyronin and Thyroxine compared to control. Recent studies have shown a general improvement of the animals health and immunity when treated by dietary of propolis (Talas and Gulhan 2009; Morsy *et al*., 2013).

IV – Conclusions

Propolis, an alternative natural additive, increased diet digestibility, N intake and microbial N supply and decreased methane emissions. Propolis represents a promising natural antibiotic with profit biological and environmental effects during the late gestation of ruminants.

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The goat meat sector in an Algerian mountain region: analysis of its value chain

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Abstract. The aim of this study is to determine the different various actors in the goat meat value chain in the mountainous region of Tizi-Ouzou. The study of sixteen goat farms from a prior survey of 80 goat farms, showed that these farms are still conducted in extensive. The goat breeding has evolved and passed from self-consumption to a production for the market. Young goats are the most sold for their tender meat. The marketing of goat meat goes through few intermediaries (actors) that structure the market. Restaurants are a new segment that integrates the value chain and ensures a better value of goat meat. The price of this meat follows that of the sheep meat. Its fluctuation follows the moments of strong demands like the Aid-Al-adha. The demand for goat meat continues to grow. Because of its dietary characteristics, goat meat is beginning to interest a growing consumer segment. For that purpose, a better knowledge of the value chain of this meat will make it possible to target the opportunities for a better structuring of the market and its development.

Keywords. Goat meat – Value chain – Market – Development – Tizi-Ouzou.

La filière viande caprine en région de montagne d'Algérie: analyse de sa chaine de valeur

Résumé. *L'objectif de ce travail est de déterminer les différents acteurs de la chaine de valeur de la viande caprine dans la région montagneuse de Tizi-Ouzou. Le suivi d'une quinzaine d'élevages, issus d'une enquête préalable sur 80 élevages caprins, a montré que ces élevages sont toujours menés en extensif. Cet élevage a évolué et est passé d'une fonction d'autoconsommation à une fonction de production destinée au marché. Ce sont les chevreaux et chevrettes qui sont les plus vendus pour leur tendre viande. La commercialisation de la viande passe par peu d'intermédiaires qui structurent le marché. Les restaurants constituent un nouveau segment qui intègre la chaine de valeur. Le prix de cette viande talonne celui de la viande ovine. Sa fluctuation suit les moments de fortes demandes comme l'Aid-Al-adha et sa demande ne cesse de croitre. Du fait de ses caractéristiques diététiques, la viande caprine commence à intéresser un segment de consommateur de plus en plus élargi. A cet effet, une meilleure connaissance de la chaine de valeur de cette viande permettra de cibler les opportunités pour une meilleure structuration du marché et son développement.*

Mots-clés. *Viande caprine – Chaine de valeur – Marché – Développement – Tizi-Ouzou.*

I – Introduction

In mountainous areas, the agro-ecological environment is adequate for extensive goat farming supported by the exploitation of pastoral resources. These farms are conducted with low expenses (Dubeuf, 2011). In 2015, goat meat production in Algeria reached a quantity of 19,115 tons, it represents only a small percentage (12%) compared to beef production (155 037 tons) (FAOSTAT, 2016). In recent years, there has been a change in consumer behaviour towards goat meat, because of better dietary and organoleptic characteristics of this meat. In the mountainous region of Tizi-Ouzou (Northern Algeria), the extensive goat husbandry is very present with mixed production (Kadi *et al*., 2013, Mouhous *et al*., 2017). Currently, the production of goat meat is changing

towards adapting their products to consumers' requirements, including the production of chevon meat (Mouhous *et al*., 2016). The aim of this work is to give an overview on the different elements of the value chain of goat meat in the Tizi-Ouzou area.

II – Materials and methods

Located in north of Algeria, the study area is distributed over an area of 2976 km² of which 50% has slopes greater than 25% (DPAT, 2010). The number of goats reached 57 305 (17% of the local total number of ruminants) (DSA 2014). From a preliminary study of 80 goat's farms, we chose 16 farms to conduct a one year follow-up. Investigators passages were made once or twice a month. In this work, we focus only on different elements of the value chain of goat meat. Surveys have also targeted another value chain actors such as resellers (livestock dealer and representative agent), butchers, restaurants and consumers.

III – Results and discussion

1. Characterization of goat farming systems

In mountainous areas, the use of the rangelands is daily and throughout the year. For the complementation, which consists of wheat bran and a mixture of barley-corn, goats receive on average 500 g / day / head throughout the year. Those results agree with those reported by Kadi *et al*. (2016). More than half of the farms (57%) have a size ranging from 30 to 100 head, and have goats from crossed populations. The farms have all followed a mixed production (milk and meat) but at different output levels depending on the amount of milk produced, as already reported by Kadi *et al* (2013).There are three categories of breeders: high production (457 l/goat), medium production (327 l/goat) and low production (189 l/goat).

2. The different actors in the goat meat value chain in the Tizi-Ouzou region

A. Breeder

As a central element of the value chain, the breeder comes upstream from the goat meat sector. Depending on the orientation of the production, breeders act on the flows of the different types of animals by selling the animals reformed or which do not have a productive interest. In the simple circuit system it is the farmer who takes his animals to the market. Breeders of the strong milk production strategy sell more chevons. They keep males and females for breeding and milk production. In the other two strategies (low and medium production) farmers sell more reproductive animals (male and female) as small (chevons).

B. Livestock dealer and representative agent

In the organization of the goat meat value chain, there are very few types of actors involved in marketing live animals. We count the livestock dealers and the representative agents. Both are also livestock dealers-breeders and agent-breeders. The livestock dealers have a significant financial windfall that allows them to make transactions at any time. There are not many representative-agents on the market. Different formulas exist for the marketing of these animals: (i) the agent tries to sell the animal at the best price on the market, in return he receives a commission; (ii) the sale is at the farm level. The transaction is done either by the breeder himself or by a representative-agent.

C. Slaughterhouses

The slaughterhouse is an important intermediate segment of the goat meat value chain. The study area has 14 slaughterhouses (6 private and 8 public) distributed in different sub-Districts. They all have a veterinarian (DSA, 2018). For the year 2018, according to the DSA, the slaughter involved a total of 6234 goats (15% of the total population of the District of Tizi-Ouzou) which produced a total weight of 1251.8 quintals of meat. However, illegal slaughter still exists but with low frequency.

D. Butchers

The butcher is another link in the value chain which takes its share of the margin. Not all butchers that sell goat meat. In addition to beef and sheep, there are some butchers who specialize in goat meat. These butchers are supplied by the market (livestock dealers, breeders) or directly from breeders on their farms.

E. Restaurants

In our case study, the restaurant represents a link in the organization of the goat meat value chain. Goat meat currently come in big cities and the restoration (Sahraoui *et al*., 2016). People who consume goats give it a festive character intended for a targeted clientele. The restaurants surveyed offer goat meat once or twice a week. This contrasts with the observations of Hadbaoui and Senoussi (2016) that show that in the s that the Algerian steppe the restaurants are not a segment of the sheep meat value chain.

F. Consumers

In the study area, there are two types of consumers; a first segment that consumes goat meat, controlled or not because of its dietary value (contains very little cholesterol) as signaled by Madruga and Bressan (2011); they are regular consumers. A second segment that consumes this meat often uncontrolled and irregularly, because of its affordable price compared to that of sheep meat. On the other hand, the bad odour felt in live goats would be one of the limiting factors in the consumption of goat meat by a large part of the population in the study area.

3. The market for goat meat in the Tizi-Ouzou region

Goats are sold in two forms; either in carcasses or on feet. There is no sale of goat carcasses on the livestock market.

A. Livestock market

Place of business transaction, the market is the space where the animals selling price is formed. There are four major livestock markets in the study area, almost distributed at the cardinal points. That of the region of Oued Aissi is the most important. But in every Daira (sub-district), there is a small local market. Livestock dealers, who are often breeders, and some big breeders are forced to attend other livestock markets in the neighboring Districts.

B. The marketing of goat meat

The carcasses of chevons and, to a lesser extent, male goats are the most popular. The most appreciate are leg of and steak. However, it is rare to find regular consumers who go directly to a breeder for the purchase of goat meat. While the quality of the meat is related to the wholesomeness and being free of pathogens and without residues (Casey and Webb, 2010).

C. The type of animals and the price of goat meat

Low and medium milk production groups have a strong sale of adult males (Table 1). Young (female and male goat kids) does not exceed 10% of sales. The small animals and are kept high for the market. While for high milk producers, sales are concentrated on male goat kids (77%) and female goat kids (14%) while the adults are kept.

Table 1. Distribution of sales of goats (no, of animals) by farms following different milk production strategies

Production modalities	Total sales	Sale male goat (%)	Sale female goats (%)	Sale female goat kids (%)	Sale chevons (%)
Low production (189 l/goat)	42	71	17	7	5
Medium production (327 l/goat)	37	76	8	8	8
High production (457 l/goat)	107	4	5	14	77

In the farms followed, the average price of male goat (usually for sacrifice) is 35 000 DA. A price variation is signalled. An average male goat of 35 kg is estimated on the market at 45, 000 DA. The selling price of goat meat at the butchers vary between 1000 and 1500 DA/kg.

IV – Conclusion

The goat meat value chain is built around a reduced number of actors. Today, valorization of this meat based on a dietetic value that channels a segment of consumers is increasingly important. The goat meat value chain requires an improvement of its chain links for a better valorization of goat meat. For example, the creation of breed farms upstream. Downstream, the development of advertising and the presence of goat meat in the shelves of outlets would also popularize this meat and capture a larger segment of consumers.

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Concerted actions to underline and promote the quality of wool and its products from local sheep breeds in Epirus

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Abstract. In Greece sheep are bred for milk (75% of income) and lamb meat (25%). Wool production, an internationally important production line, is nowadays considered worthless and in most cases, sheep wool is discarded resulting a burden for the environment. The aim of this study was to make known the actions that have been taking place in Epirus (Western Greece) since 2015, in order to underline the advantages of sheep wool from local breeds and to explore alternative uses for commercial exploitation. Firstly, Idea Generation Meetings between representatives of local agents (AGRCI and ATSBE) and the ATELIER "Wools of Europe" were held and a specific 5 year action plan was designed. Secondly, a number of wool quality analyses in three local sheep breeds (Katsika, Kalarrytiki and Frizarta, n=159) were carried out so as to explore the specific characteristics of their wool. Additionally, the "Sheep Wool Day 2017" festival was organized in Epirus, which included scientific conference, display of wool products, book and photo exhibition and children's workshops relative to wool. Finally, the possibility of using wool from the above sheep breeds as an insulating material was investigated with encouraging results. Seeking new alternative uses of wool is expected to add value to the textile product and improve farmers' income.

Keywords: Sheep – Breeds – Wool – Greece.

Races ovines locales en Épire et perspectives d'exploitation de la laine

Résumé. *En Grèce, les ovins sont élevés pour le lait (75% du revenu) et la viande d'agneau (25%). La production de laine, une chaîne de production d'importance internationale, est aujourd'hui considérée comme inutile et dans la plupart des cas, la laine de mouton est rejetée comme un fardeau pour l'environnement. Le but de cette étude était de faire connaître les actions en cours en Épire (Grèce occidentale) depuis 2015, afin de souligner les avantages de la laine de mouton de races locales et d'explorer la recherche d'utilisations alternatives à des fins d'exploitation commerciale. Premièrement, des Réunions de génération d'idées entre des représentants d'agents locaux (Centre de ressources zoo génétiques de Ioannina, Association des éleveurs de transhumance) et l'ATELIER «Laines d'Europe» ont eu lieu et un plan d'action de 5 ans a été conçu. Deuxièmement, un certain nombre d'analyses de la qualité de la laine chez trois races de moutons locales (Katsika, Kalarrytiki et Frizarta, n = 159), ont été réalisées de manière à explorer les caractéristiques spécifiques de leur laine. En outre, le festival «Journée de la laine ovine 2017» a été organisé à Épire. Il comprenait une conférence scientifique, une exposition de produits en laine, de livres et de photos et des ateliers pour enfants relatifs à la laine. Enfin, la possibilité d'utiliser de la laine provenant des races de moutons susmentionnées comme matériau isolant a été étudiée avec des résultats encourageants. La recherche de nouvelles utilisations alternatives de la laine devrait ajouter de la valeur au produit textile et améliorer les revenus des agriculteurs.*

Mots-clés. *Moutons – Races – Laine – Grèce.*

I – Introduction

In the entire Mediterranean region and particularly in Greece, sheep and goat farming is the main livestock production sector, with a significant contribution to the national economy, rural sustainability & development and preservation of life in countryside (Di Trana *et al.*, 2015). Sheep and goat

farming offers many comparative advantages, due both to the specific environmental conditions of Greece and to tradition emerging through the centuries as part of its cultural heritage. Thousands of families obtain or supplement their income from small ruminant farming.

Sheep in Greece are mostly bred for milk production which accounts for approximately 75% of the producer's income, while lamb meat production accounts for 25% of it. However, sheep wool has a marginal economic value for farmers. Wool is the product harvested in sheep's compulsory shearing at the end of spring or early summer and contributes almost nothing to the farmer. On the contrary, in some other countries worldwide (e.g. Australia and New Zealand), wool production is the main productive and economic line of sheep farming.

In 2017, sheep population in Greece was 8 592,619 in 87,109 flocks (ELSTAT, 2017). It is worth noting that the statistics over time (since 2002) show that the number of sheep has remained relatively stable, while flocks have decreased by around 20%. In the region of Epirus, in the same year 714,551 sheep were bred (8.3% of the country) while the sheep flocks were 9,351 (10.1% of the country). Finally, since 2002, the average size of sheep flocks is low, around 78 sheep and 38 goats (ELSTAT, 2017). From the total population of sheep, only a small part (about 5%) is classified as pure breeds. Furthermore, the population of these breeds has been reduced and some of them are threatened by genetic erosion and extinction. In Epirus, the purebred sheep amounts to lowlands about 65,000. The most populous breed is Frizarta, which is a domestic "synthetic" breed that was created in the flat part of the region of Arta. It has high milk yield and adjustability in a wide range of humidothermal conditions. Its wool is semi-fine with production around 1.5 kg per animal. The other purebred breeds are Katsika Ioanninon, Kalarritiki, Mountain breed of Epirus and Sarakatsaniki, which are threatened indigenous breeds with very low population (1163, 6961, 1639 and 4754 total animals, respectively). Their wool production is between 1.5 and 1.8 kg. These breeds have some common characteristics such as disease resistance, durability to adverse and changing weather conditions, ability to use poor pastures and to survive on limited food and water resources. Ewes milk yield and lamb meat production of the above breeds are low and they do not cover the demands of the modern intensive sheep farming systems. On the contrary, many wool analyses have shown that the quality of their products is exceptional (Kondyli *et al.*, 2012).

The wool-productive sheep breeds produce extremely thin wool, which is used by the yarns industry for fabrics, clothes, knits, etc. (Chaupin, 2005). The majority of sheep breeds in Greece have long coarse-wool fleece. The main feature distinguishing the Greek wool is its great heterogeneity. Breeds have evolved over time and there are no recent studies on the wool traits. In the past many craftsmen manufactured carpets, flocks, blankets, duvets, pillows, capes, trays and other utilitarian items, but since the country's entry into the EU (in 1980) the wool processing industry has shrunk and almost disappeared. In recent years, efforts are being made to exploit the wool so that it is not a waste of rearing.

In the past, wool production provided a low additional income for the small ruminant farmer. Unfortunately, today it is only a by-product of sheep farming, often rejected as a process, because it is considered unprofitable. In addition, the price of the wool is so low in some cases that it does not cover the expenses for the harvest. The aim of this study was to make known the actions that have been taking place in Epirus (Western Greece) in order to highlight the advantages of sheep wool from local breeds and to propose alternative uses for commercial exploitation.

II – Materials and methods

A number of actions have taken place in Epirus (Western Greece) since 2015 in order to show the advantages of sheep wool from local breeds. They can conveniently be sorted out as Workshops and Wool Quality Analyses:

1. Workshops

A number of Idea Generation Meetings between representatives of local agents (Animal Genetic Resources Center of Ioannina –AGRCI, Association of Transhumance Stock Breeders of Epirus –ATSBE) and the ATELIER (European Association for Study, Liaison, Innovation, Research into Textiles) "Wools of Europe" were held in Epirus and a specific –5 year– action plan was designed since 2015. The representative of the local wool handcrafters contributed their experiences from the wool market and presented the problems they face. Two sheep farmers offered gratis the annual wool production of their Katsika breed flocks in order to be examined from the specialized laboratory of the Agricultural University of Athens and additionally to be used by a handicraftsman to create exquisite products, adjusted to the type of the wool.

Moreover, the "Sheep Wool Day 2017" festival was organized in Epirus, to present the wool products that were produced and to promote the advantages of wool. The festival included scientific conferences, display of wool products, book and photo exhibition and children's workshops relative to wool (Pappas, 2017). Subsequently, 15 farmers from Greece participated in a 15 days mobility program in South France for training on wool actions in 2018.

2. Wool quality analyses

Firstly, a study was carried out in order to estimate the quality of wool in two Greek sheep breeds reared in Epirus: (i) Kalarrytiki (KL) and (ii) Katsika Ioanninon (KI), with the ultimate goal of highlighting the quality of the wool and exploring the possibilities of its utilization. The sampling took place from April to June 2016. 50 and 56 samples from KL and KI were analyzed. The samples were assessed for the thinness of the wool (estimation of the fiber diameter) with optical microscope, the length of the staples and the weight of unwashed wool.

Secondly, a study is in process since May 2018. It includes 53 samples from Frizarta breed, assessing the same wool traits.

Thirdly, another study has been carried out in order to investigate the possibilities of using wool for the manufacture of composite materials. Specifically, the length of the staples, the weight and the diameter of wool were measured in samplings from 34 animals of the KL and KI sheep breeds. Then, a polymer composite matrix material was created which included the epoxy resin as a matrix material and the wool as the fibrous material. Ten (10) wool samples of each breed were constructed. The processing formulation of the samples was carried out in a heated pressure chamber. Mechanical properties measurements followed such as Bending Testing and Shear Testing.

II – Results and discussion

Based on the results of the first study, the wool diameter was significantly higher in the KL compared to KI breed. Additionally, the effect of sex was significant with rams having longer diameter than ewes, while statistically significant differences were found among flocks in each breed. The variance coefficients expressing the degree of heterogeneity for wool diameter in each individual showed that there was a very large heterogeneity for this trait (Xarchakos *et al*., 2017). Thin diameters (<30 μ) are extremely small and the majority of fibers have a diameter of 40 – 80 μm. Considering that KI and KL breeds are milk productive breeds and milk production is negatively correlated with wool production, specifically with the thinness of the fiber, account for the fact that Greek wools are not used in weaving fine fabrics, because the resulting fabrics give the sense of roughness in direct contact with the human skin. The quality of Greek wool makes it more suitable for the textile industry for the fabrication of carpets or for other alternative uses.

The results of the third study concluded that the mechanical properties of the epoxy resin are not degraded when combined with sheep wool. Additionally, it was found that adding wool to an epoxy matrix causes a slight increase in flexural strength of the composite material (Pardou *et al.*, 2018). Furthermore, it can be concluded that wool can enhance thermal insulation performance of compound materials by a significant percentage. Specimens with wool of KL breed had a coefficient of thermal conductivity reduced by 25%, while specimens with wool from the KI breed by 30%. The different heat-insulating behavior of composite materials with sheep wool is probably due to differences in the diameter of the wool.

III – Conclusions

According to the International Wool Textile Organization (IWTO), "all wool finds its use" (www.iwto.org). It is a natural and renewable resource that is produced invariably every year. Wool has many natural properties that are beneficial for health, wellness and comfort. Wool products, for example, can offer UV protection, humidity control, high thermal resistance, breathability, sound reduction and toxic chemical absorption. Considering its unique properties makes it worth rediscovering and reconfiguring it. The amount of wool produced each year in Greece and generally around the Mediterranean region, is so high that it is worth trying to bring it back to the production system. Additionally, the use of wool for the manufacture of composite materials will contribute to the construction of products that are durable and environmentally friendly. Also, the adaptation of the use of wool to the requirements of modern society (layers, pillows, clothing, thermal insulation, sound insulation etc.) is expected to boost wool production. The collaboration of the domestic crafts with industries that are involved in the production process can help towards this direction. The consumers should be informed and made aware of the benefits of wool products compared to both synthetic and cotton wool.

Seeking new alternative uses of wool, classifying it on the basis of quality and certifying the sheep breed it originates from, is expected to add value to the product and improve farmers' income.

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Exploration des potentialités de développement d'un nouveau produit laitier à base de dattes dans les oasis d'Ouarzazate (Maroc)

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Résumé. L'oasis Marocaine est un vaste territoire qui associe l'élevage caprin à des cultures végétales dont principalement le palmier dattier. Dans la région d'Ouarzazate, des coopératives féminines développent des activités basées essentiellement sur la vente et la transformation du lait de chèvre en fromage. Ces activités constituent une source insuffisante de revenus pour ces femmes et leurs foyers. Dans ce contexte, ce travail a été réalisé dans l'objectif d'identifier les possibilités et les opportunités d'une valorisation plus rentable du lait de chèvre par ces coopératives. Le travail a été basé sur des enquêtes de terrain et des discussions avec les dirigeantes de 30 coopératives potentielles de la région. Les résultats montrent que toutes les adhérentes de ces coopératives disposent d'un petit cheptel caprin de 3 à 4 chèvres de race « Alpine » et « Drâa » ; en plus, 81% de ces adhérentes possèdent des vergers de dattes. Cette datte, de très faible valeur marchande, est destinée à l'autoconsommation. L'excédent est transformé par un procédé traditionnel en aliment de bétail. Les enquêtes ont révélé aussi que le l'adhésion de toutes ces coopératives à une unité de valorisation du lait (basée actuellement à Ouarzazate) constitue une potentialité pour développer un yaourt à base de morceaux ou de sirop de dattes. Cette unité dispose des équipements et du savoir-faire permettant de développer et commercialiser ce produit laitier, qui pourra constituer une source des revenus supplémentaires pour les coopératives féminines.

Mots-clés. Coopérative – Lait de chèvre – Datte – Femme – Oasis.

Exploration of potentialities of development of a new dairy product based on date fruits in the oases of Ouarzazate (Morocco)

Abstract. *The Moroccan oasis is a vast territory that combines goat farming with plant crops, mainly the date palm. In the Ouarzazate region, women's cooperatives develop activities based mainly on the sale and processing of goat's milk into cheese. These activities are an insufficient source of income for these women and their homes. In this context, this work was carried out with the objective of identifying the possibilities and opportunities for a more profitable valorisation of goat milk by these cooperatives. The work was based on field surveys and discussions with agents of 30 potential cooperatives in the region. The results show that all members of these cooperatives have a small goat herd of 3 to 4 Alpine and Drâa breed; in addition, 81% of these members own date orchards. This date fruit, of very low market value, is intended for self-consumption. The surplus of date production is transformed through a traditional process into livestock feed. The surveys revealed, also, that the membership of all these cooperatives to a milk valorization unit (currently based in Ouarzazate) constitutes a potential for developing a yogurt based on date fruit or syrup. This unit has the equipment and know-how to develop and market this dairy product, which can be a source of additional income for women's cooperatives.*

Keywords. *Cooperative – Goat milk – Date-palm – Woman – Oasis.*

I – Introduction

A l'échelle des oasis, la femme occupe une place prépondérante dans le tissu coopératif et dans le fonctionnement des unités de production vu la migration des hommes dans les régions Nord du Maroc ou à l'étranger. Aussi, les coopératives féminines dans cette région focalisent leurs activités dans le développement économique de leur terroir à travers des activités génératrices de revenus tel que la valorisation des produits locaux (MAES, 2017). Cette valorisation se limite à la transformation du lait en fromage frais malgré l'excédent laitier qui s'oriente vers l'autoconsommation (Noutfia *et al.,* 2016). En plus, les oasis Marocaines sont réputées par la diversité des génotypes de palmier dattier (*Phoenix dactylifera* L.) : 453 variétés de dattes y ont été recensées, à côté des khalts (hybrides issus d'un semis naturel) qui représentent environ 55 % de l'effectif total (INRA, 2011). Cependant, la valorisation de la datte reste, à l'instar du lait, insuffisante et se limite actuellement à la transformation en sous produits comme le sirop, la confiture, la pâte (Harrak *et al*., 2018). Or, d'autres potentialités de valorisation se présentent comme l'incorporation de ce fruit noble dans des produits laitiers. Dans ce contexte, ce travail a été réalisé dans l'objectif d'identifier les opportunités d'une valorisation plus rentable du lait de chèvre et de la datte par ces coopératives.

II – Matériel et méthodes

Un questionnaire d'enquête a été préparé pour comprendre 'la place' de la datte dans la vie quotidienne des coopératives féminines de la région d'Ouarzazate et de dénicher, par la suite, les voies possibles d'une valorisation plus rentable de ce fruit. Les enquêtes ont étés réalisées auprès de 30 femmes dans cinq localités :

- Zaouiet Sidi Othmane ;
- Tagharamte ;
- Isfoutalil ;
- Tifoultoute ;
- Tamassinte.

Le choix des sites d'enquêtes et des coopératives enquêtées a été fait conjointement avec des établissements régionaux de développement et de vulgarisation agricole dans le cadre d'un atelier participatif. Ainsi, la structure des coopératives féminines ayant contribué à ces enquêtes se présente comme suit (Fig. 1).

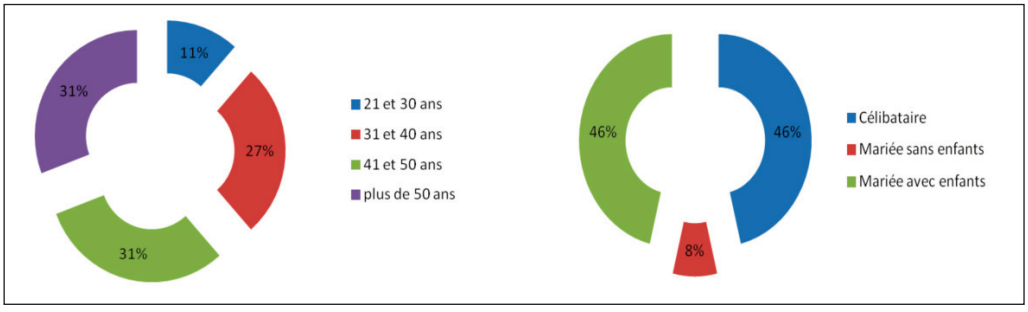

Fig. 1. Situation familiale et tranche d'âge des femmes relevant des coopératives féminines de la région d'Ouarzazate.

A noter que toutes les coopératives féminines enquêtées adhérent à une unité semi-industriel (COROSA) qui oriente ses activités dans la transformation du lait en fromage frais et semi affiné.

III – Résultats et discussion

1. Importance élevage

Dans la région d'Ouarzazate (concernée par ces enquêtes), les coopératives féminines disposent d'un nombre moyen d'environ 4 têtes de chèvre et 4 têtes de brebis par foyer (cf. Fig. 2). Cependant, le cheptel bovin n'a été recensé qu'avec un pourcentage très faible de 0,15%. L'élevage pratiqué est de type intensif pour toutes les coopératives.

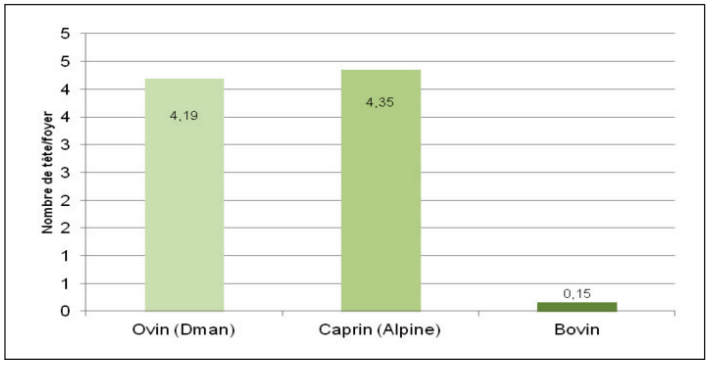

Fig. 2. Répartition moyenne du cheptel au sein des foyers féminins de la région d'Ouarzazate.

Pour la production du lait de chèvre, une moyenne de 2,4 litres/jour/tête a été notée. Cette production est orientée principalement vers la vente (85%) à l'unité de fabrication COROSA de fabrication du fromage ; de ce fait, l'autoconsommation ne dépasse pas 15%.

2. Place et valorisation de la datte

Au niveau des foyers enquêtés, 84% des femmes oasiennes disposent des pieds du palmier dattier (cf. Fig. 3). Cet effectif se compose principalement des khalts (56%) et du mélange khalts et variétés de dattes connues (20%). Les khalts cultivés par ces coopératives sont caractérisés par des petits calibres et une teneur en eau faible (dattes sèches). Aussi, ces khalts sont principalement dénommés : *Metrouh* et *Sayer*. La production moyenne en dattes a été estimée à 76 kg/pied et le nombre moyen des pieds (arbres) recensé pour chaque foyer féminin est de 16.

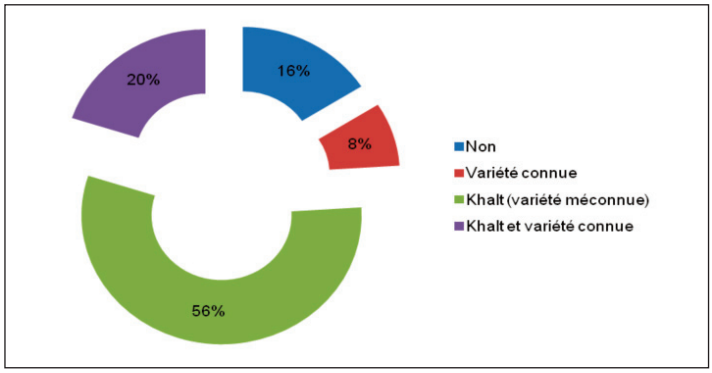

Fig. 3. Distribution du palmier dattier dans les foyers des coopératives de la région d'Ouarzazate.

Les coopératives ne disposant de dattes achètent ce fruit au niveau des souks et marchés locaux à un prix moyen de 24 Dirhams/kg. Les quantités achetées varient considérablement d'un foyer à l'autre. Ainsi, il a été enregistré que ces quantités peuvent atteindre jusqu'à 400 kg (pour une utilisation ultérieure en tant qu'aliment de bétail) par foyer et dans certains cas, cette quantité ne dépasse pas 2 kg (c'est le cas d'autoconsommation).

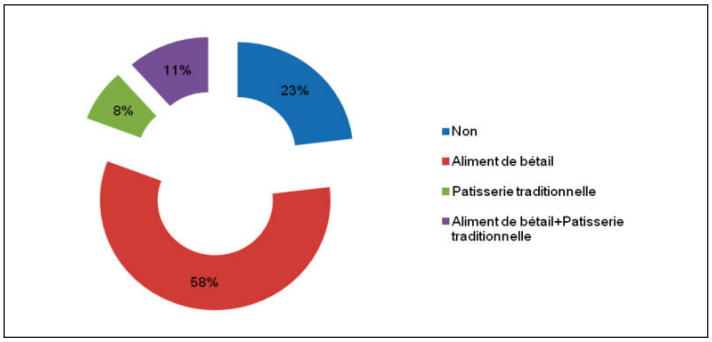

Fig. 4. Destination de la datte cultivée et achetée par les membres des coopératives féminines de la région d'Ouarzazate.

La Figure 4 relate qu'environ ¼ de ces coopératives n'ont aucun savoir faire en matière de transformation des dattes. Pour cette catégorie, la datte est consommée sans aucune transformation à l'échelle des ménages. Cette figure montre, aussi, que plus de la moitié des coopératives ont recours à une valorisation des dattes à faible valeur marchande en aliments de bétail (principalement pour les chèvres). Ce type de valorisation se fait en procédant par un séchage solaire traditionnel (sous les rayons solaires) des dattes d'une durée moyenne de 10 mois. Après séchage, les dattes sont broyées et mélangées avec des aliments tel que : la paille, l'avoine, le son de blé, morceaux de pain, l'orge… Par ailleurs, les femmes relevant de ces coopératives ont manifesté un grand intérêt à une valorisation plus rentable de leurs lait et dattes à travers d'autres produits dont principalement le yaourt de dattes.

IV – Conclusions

La présente prospection a montré que le l'adhésion de toutes les coopératives à une unité de valorisation du lait (COROSA) pourrait constituer un canal prometteur pour le développement d'un yaourt à base de morceaux ou de sirop de dattes. Cette unité dispose des équipements et du savoir-faire permettant de développer et commercialiser ce produit laitier, qui constituerait une source des revenus supplémentaires pour les coopératives féminines.

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Biodiversity associated to European sheep grazed pastures

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Abstract. We analysed the biodiversity of foliage arthropods in nine sheep grazed pasturelands in five European countries. During the maximum flowering period in 2018, entomofauna was collected in 4-6 areas within each pasture, performing 6 transects/area and 25 sweeps per transect. Multivariate analyses tested the differences in total arthropod community composition among degrees of intensification, bioregions and types of pastures. A total of 51,474 arthropods from 3 classes, 17 orders and 95 taxonomical groups were recorded. Univariate analyses revealed that total arthropod abundance was higher in extensive than in intensive systems ($P<0.01$). It also differed between bioregions (higher in Alpine than in Continental, $P<0.05$) and between types of pastures (higher in mountain than in lowland pastures where animals are supplemented, $P<0.05$). Total taxa richness was not influenced by any of the three factors. However, multivariate analyses indicated that community composition differed among intensive and extensive systems, bioregions and types of pastures ($P<0.001$). The greatest differences occurred between Alpine and Mediterranean ($P<0.001$), and Mediterranean and Continental pastures ($P<0.05$), as well as between lowland seminatural and improved pastures ($P<0.05$), and seminatural and mountain pastures ($P<0.001$). These results reveal the complex and varied communities associated to the diverse sheep systems and valorise the role of the more extensive, mountain and natural pastures for the conservation of biodiversity in sheep grazed areas.

Keywords. Arthropods – Biodiversity – Sustainability – Management.

Biodiversité associée aux pâturages de moutons européens

Résumé. *Nous avons analysé la biodiversité des arthropodes du feuillage dans neuf pâturages situés dans cinq pays européens et pâturés par des moutons. La faune a été collectée dans 4-6 zones de chaque pâturage, effectuant 6 transects/zone et 25 balayages/transect. 51 474 arthropodes de 3 classes, 17 ordres et 95 groupes taxonomiques ont été enregistrés. Des analyses univariées ont révélé que l'abondance d'arthropodes était plus élevée dans les systèmes extensifs que dans les intensifs (P<0,01). Il diffère également entre les bioregions (plus élevées dans les Alpes que dans les Continentales, P<0,05) et entre les types de pâturages (plus élevées dans les pâturages de montagne que dans les plaines où les animaux sont supplémentés, P<0,05). La richesse totale des taxons n'a pas été influencée par aucun des trois facteurs. Les analyses multivariées ont indiqué que la composition de la communauté différait entre les systèmes intensifs et extensifs, les bioregions et les types de pâturages (P<0,001). Les différences les plus marquées ont été observées entre les pâturages alpins et méditerranéens (P<0,001), méditerranéens et continentaux (P<0,05), ainsi qu'entre les pâturages semi-naturels et améliorés des plaines (P<0,05). Ces résultats révèlent les communautés complexes et variées associées aux divers systèmes ovins et valorisent le rôle des pâturages plus étendus, montagnards et naturels, pour la conservation de la biodiversité dans les zones de pâturage ovin.*

Mots-clés. *Arthropodes – La biodiversité – La durabilité – La gestion.*

I – Introduction

Sheep are of great importance as a major source of livelihood of the small farmers and the landless in rural communities, and they also contribute to peri-urban and increasingly to urban households by providing food, income, socio-cultural wealth, clothing, etc. Therefore, their management can have multiple impacts including food safety and security in some areas (Scortichini *et al*., 2017). Additionally, sheep farming systems interact with the environment and the link between animal production and natural environment is acquiring more importance for the sustainability of the farm system (de Rancourt *et al*., 2006). In parallel, consumer awareness about quality and sustainability of the production cycle of animal food products is also increasing. In this paper we evaluated the biodiversity of arthropod fauna in nine sheep grazed pasturelands located in five European countries which include different bioregions, types of pastures and degrees of intensification.

II – Materials and methods

1. Study sites

A total of 9 farms, which had pastures available for sheep grazing, were surveyed to assess their arthropod abundance and diversity. The pastures were located in Germany, Italy, Portugal, Slovenia and Spain. Each site was characterized according to the bioregion, the type of pasture available to sheep (from grasslands and grazed forests to pastures combined with indoor supplementation during the grazing season) and its management system (degree of intensification) (Table 1).

Table 1. Description of the farms according to the country, bioregion, type pasture and type of management. N: number of sampling areas within each site

Country	Site	Bioregion	Pasture	Management	N
Germany	AG	Continental	GF	Extensive	4
Italy	IT	Alpine	MP	Extensive	5
Portugal	ESA	Atlantic	PS	Intensive	4
Portugal	SE	Atlantic	SG	Extensive	4
Portugal	GEO	Mediterranean	GF	Extensive	4
Portugal	IP	Mediterranean	PS	Intensive	4
Slovenia	SL	Alpine	MP	Extensive	4
Spain	SC	Atlantic	IP	Extensive	6
Spain	SS	Atlantic	IP	Extensive	6

GF: grassland-forests; IP: improved pastures; MP: mountain pastures; PS: improved pastures and nearby indoor supplementation, SG: seminatural grasslands.

2. Sampling and statistical analyses

The arthropods were sampled by sweep-netting in 4-6 areas per farm during the maximum blooming period of the pastures in 2018. In each area 6 random transects were established and within each one 25 sweep nets were performed. All the arthropods from each transect were transferred to a re-sealable zipper bag for further analyses in the laboratory. Arthropods were classified to Order level, and within the Orders Araneae, Hemiptera, Orthoptera and Coleoptera, to family level. ANOVA analyses were performed with SPSS 23 version to test differences in abundance and diversity of arthropods between management types, bioregions and types of pastures. To investigate differences in fauna composition among the same factors, we used permutation-based hypothesis testing (ANOSIM analyses) implemented in PRIMER 6.1. Multi-dimensional scaling (MDS) plots were generated to visualize differences in arthropod assemblages among factor levels. Similarity

was determined using the Bray-Curtis similarity coefficient. The sampling areas were the experimental units for the statistical analyses and data were log (x+1)-transformed when necessary to meet ANOVA assumptions. Post hoc comparisons were performed using the Bonferroni adjustment.

III – Results and discussion

The dataset during this first sampling period included 51,474 arthropods from 3 Classes, 17 Orders and 95 taxonomical groups. The most abundant groups were Diptera (34.4% of all individuals), Homoptera (14.9%), Symphypleona (14.9%), Coleoptera (11.7%) and Hymenoptera (9.7%). Univariate analyses revealed that total abundance of arthropods was higher in extensive (mean standard deviation: 1375.5 individuals 843.8) than in intensive (760.4 489.2) farms ($P<0.01$). A general positive trend with arthropod abundance increasing along decreasing stocking rate gradients has been reported in previous studies (Scohier and Dumont, 2012), although taxa-specific responses have been frequently reported (Rosa García *et al*., 2009). Total arthropod abundance also differed between bioregions ($P<0.05$), with the highest differences ($P<0.05$) between Alpine (1771.1 individuals 569.6) and Continental (593.8 185.8) areas. Traditional farming and the related practices in mountain areas are often associated with high biodiversity, and there are increasing efforts to maintain them in order to mitigate the impacts of their decline on mountain landscapes and biodiversity (Pykälä, 2000). The type of pasture was also important ($P<0.05$), and total abundance was higher ($P<0.01$) in mountain pastures (1771.1 individuals 569.6) than in lowland pastures (760.4 489.2). Mountain pastures are characterized by lower degree of specialization and use more environmentally friendly farming practices than more modern systems (Marini *et al*., 2011). Total taxa richness was not influenced by any of the three factors.

Multivariate ANOSIM tests indicated that community composition differed between intensive and extensive systems, bioregions and types of pastures ($P<0.001$). The subsequent pairwise tests for the different bioregions indicated that the greatest differences occurred between Alpine and Mediterranean (R^2: 0.83; $P<0.001$), and Mediterranean and continental pastures (R^2: 0.88; $P<0.05$). The MDS analysis helped to visualize those differences (Figure 1). A gradient from Alpine and Continental sites on the left side was followed by Atlantic conditions and the Mediterranean sites on the opposite right side. Analysing broad biogeographical patterns in species assemblages constitutes a critical step towards elucidating the factors shaping them (Rosenzweig, 1995). Regarding the differences between the types of pastures, the ANOSIM test detected the strongest differences in fauna composition between lowland improved and seminatural pastures (R2: 9.993; $P<0.05$), and between seminatural and mountain pastures (R: 0.952; $P<0.001$). The most similar strategies regarding pasture availability were seminatural pastures and systems where sheep had pastures and additional supplementation available (R: 0.149), and seminatural pastures and grassland-forests (R: 0.156).

IV – Conclusions

The arthropod communities are useful bioindicators to assess differences between farming systems and they can be a valuable tool to valorise the role of traditional extensive, mountain and natural pastures for the conservation of biodiversity in European sheep grazed areas. In this indicative study arthropod community composition was influenced by the type of pasture, bioregion and management, reflecting the diversity of environmental scenarios existing across European pastures. Globally, abundances of foliage arthropods were higher at more extensive, traditionally managed pastures compared to those more intensively managed. Further research with increased replication and sampling periods will clarify these patterns.

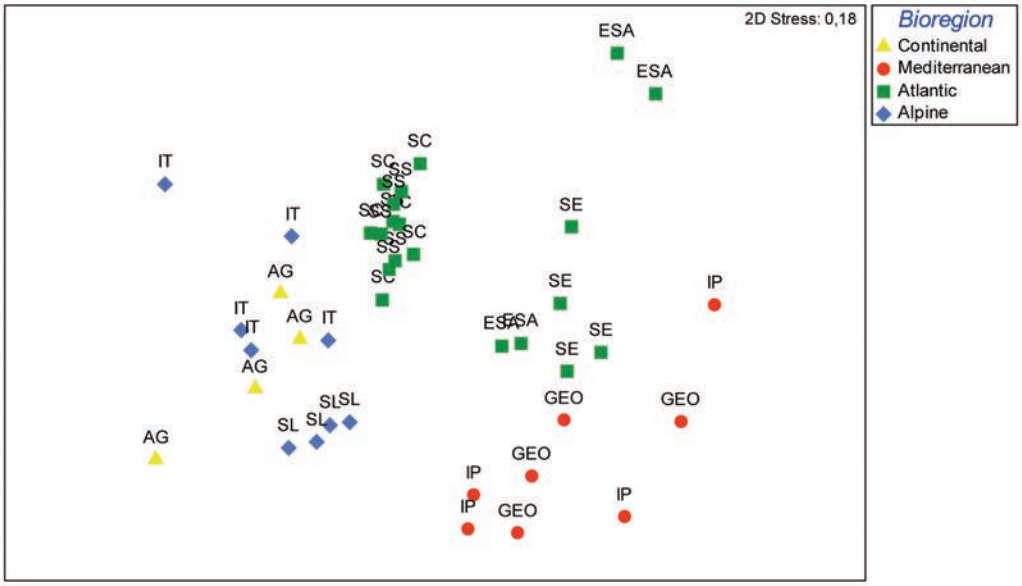

Fig. 1. MDS ordination of the 4-6 areas of each farm according to the arthropod composition and abundance (log (x+1)-transformed). Information about the codes of the farms and the sampling units within each one is included in Table 1.

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Caractérisation des exploitations spécialisées dans la production de viande bovine à Cantabria du point de vue de la gestion du territoire

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Résumé. Les fermes d'élevage constituent la base économique, sociale et territoriale de l'agriculture à Cantabria. Actuellement, un peu plus de 72% des fermes, ayant des vaches à Cantabria, sont spécialisées en production de viande. Celles-ci sont principalement situées à l'intérieur de la région et dans les zones de montagne, où la gestion habituelle est le pâturage libre du bétail dans les pâturages communaux (présents sur un tiers du territoire). L'objectif de ce travail est de caractériser, du point de vue productif et socioéconomique, le cheptel bovin à Cantabria, en accordant une attention particulière au territoire (pâturages et terres communales). À cette fin, une enquête directe a été réalisée dans 92 exploitations.

Mots-clés. Bovins – Production de viande – Gestion du territoire – Pâturages communaux – Cantabria.

Characterization of beef cattle farms in Cantabria, from the management of the territory

Abstract. *The farms with cattle constitute the economic, social and territorial basis of agriculture in Cantabria. Currently, more than 72% of farms with cows in Cantabria are of meat. These are mainly located in the interior strip and in mountain areas, where the usual management is the free grazing of cattle in the communal pastures, which account for a third of the community's territory. The objective of this work is to characterize, from the productive and socioeconomic point of view, and from a survey of 92 farms, cattle herds with beef cows in Cantabria, paying special attention to the management of the territory.*

Keywords. *Beef cattle – Meat production – Land management – Common pastures – Cantabria.*

I – Introduction

À Cantabria, région située au Nord de l'Espagne, les pâturages communaux (PC) occupent un tiers du territoire et les pâturages herbacés représentent 44,2% de la surface agricole utile (SAU) (Fernández, 2007). Ces surfaces étant directement liées à la contribution des services écosystémiques, elles sont donc au centre de la nouvelle architecture verte de la PAC. Ils constituent, traditionnellement, la principale ressource alimentaire de l'élevage de bovins destinés à la boucherie situés, principalement, dans les régions de l'intérieur et de la montagne, où la gestion habituelle consiste au pâturage libre de bovins dans les pâturages communaux.

D'autre part, l'élevage bovin est un secteur stratégique dans cette région en raison de son importance économique, sociale et territoriale, puisqu'il représente 63,7% du nombre total d'exploitations, 54,1% de la SAU, 78,5% des unités de travail agricoles (UTA), 95,6% des unités d'élevage (UG) et 93,4% du produit standard total (PET) (INE, 2019). Au cours des dernières décennies, son évolution a été marquée par un processus d'ajustement structurel intense, qui a entraîné une forte concentration d'exploitations et un processus de réorientation de la production laitière vers la viande (Arnalte, 2007 ; Vázquez *et al*., 2017).

Compte tenu de la centralité des bovins à viande dans la gestion du territoire et de ses implications, ce papier a pour objectif de permettre une caractérisation productive et socio-économique de l'élevage de vaches de boucherie à Cantabria. On prête spéciale attention à la gestion territoriale dans le sens de l'utilisation des pâturages communaux et les soi-disant ports communaux.

II – Méthodologie

Une enquête a été menée entre juin 2017 et avril 2018, au moyen d'un entretien personnel direct à 92 exploitations agricoles. La sélection initiale a été effectuée sur la base du nombre de vaches, en utilisant un échantillonnage aléatoire stratifié de la variance minimale de Neyman, avec une erreur d'échantillonnage de 5% et un niveau de confiance de 95% (Tableau 1).

Tableau 1. Caractéristiques de l'échantillonnage des fermes d'élevage de bovins à viande. 2016

Nº vaches	Nº exploitations	Nº Entretiens	Facteur d'élévation[1]
< 10	2.036	23	88,5
10 à 29	1.246	33	37,8
30 à 49	498	13	38,3
50 à 99	294	16	18,4
≥100	39	7	5,6
TOTAL	4.113	92	44,7

[1] Le facteur d'élévation est le quotient de la population parmi le nombre d'enquêtes.
Source: Données de l'enquête.

Les résultats se présentent en se référant à l'ensemble de la population (Sineiro *et al*., 2013) et cela est fait à partir du module Échantillons Complexes du logiciel SPSS, qui utilise le facteur d'élévation. Ce logiciel réalise des analyses statistiques descriptives (valeurs moyenness et fréquences) et le Modèle Linéaire Général Univarié pour la détermination de différences statistiques significatives.

Les résultats sont présentés selon trois niveaux de gestion du territoire : non communal (NPC), pâturages communaux (PC), pâturages et ports communaux (PPC)[1]. Pour cela faire, nous avons utilisé le Module d'échantillons complexes du programme statistique SPSS et le Modèle linéaire général univarié pour trouver les différences statistiquement significatives.

$$n = \frac{\sum_{h=1}^{L} Nh^2 Sh^2}{\left(\frac{E^2 Y^2}{K^2}\right) + \sum_{h=1}^{L} NhSh^2}$$

$$nh = n \frac{NhSh}{\sum_{h=1}^{L} NhSh}$$

Équation 1. Détermination de la taille de l'échantillon (n) et de la distribution en fonction des strates (nh)

n= taille de l'échantillon ; nh= taille de l'échantillon par strate ; E= erreur maximale de l'échantillonnage ; K= coefficient associé au niveau de confiance ; Y= valeur de population de la variable i (SAU) ; Sh= écart type de la variable i (SAU) au strate dans la strate j ; Sh²= variance de la variable i (SAU) dans la strate j ; et L= dernier strate.

1. La dénomination pâturages et ports communaux fait référence aux pâturages communaux de montagne d'autres régions, utilisés en régime de transhumance. En conséquence, les exploitations qui utilisent les pâturages communaux se situent, seulement, à Cantabria et celles qui utilisent les pâturages et ports communaux se localisent à Cantabria et d'autres régions.

III – Résultats

Les résultats suivants sont une extrapolation des données de l'enquête élevées à la population de Cantabria, en appliquant la méthodologie décrite au point précédent. Le pâturage libre sur des communaux est une gestion courante dans les élevages à Cantabria (Tableau 2). Sur les 4.113 élevages de bovins de boucherie existant en 2016 (donnée à 29/6/16, SITRAN, 2017), 55,1% utilisent des surfaces communales dans leur système de gestion. Les PC constituent, donc, une ressource alimentaire de premier ordre pour les bovins à viande. A ces exploitations s'ajoutent 200 exploitations qui, outre l'utilisation de ces pâturages communales, pâturent également dans des pâturages communaux, situés en dehors de la région. D'autre part, 39,9% du total des exploitations n'utilisent pas les PC et se situent principalement dans la bande côtière. En outre, le plus grand nombre des exploitations PC sont des entreprises familiales, et 1,9% seulement des exploitations qui utilisent ces espaces adoptent un type de formule d'entreprise en forme de société (elles atteignent 10,2% dans le NPC et cette formule n'existe pas dans le PPC), dont la plupart sont aussi des exploitations familiales.

Tableau 2. Distribution des variables liées aux caractéristiques productives chez les vaches à viande, en fonction de l'utilisation des pâturages communaux. 2016

Fermes et bétail	NPC[1]	PC[2]	PPC[3]	Total
Nº de exploitations	1.647	2.266	200	4.113
Sociétés (% expl.)	10,2	1,9	0	5,2
Nº vaches à viande	21.541	67.600	12.031	101.172
Vente de veaux (nº) par exploitation	9,0 c	20,5 b	42,4 a	17,0 **
Total de vaches par exploitation	13,1 c	29,8 b	60,1 a	24,6***
Charge de bétail (vaches/ha SAU)	0,9 b	2,3 a	2,4 a	1,7***

Signification statistique: *** 0,1% ; ** 1% ; * 5% ; t tendance (5-10%); ns ≥ 10%. Les sous-indices avec des lettres différentes indiquent des sous-ensembles homogènes très différents au niveau de 5%.

[1] Pas de pâturages communaux. [2] Pâturages communaux. [3] Pâturages et ports communaux.

Le plus grand nombre de vaches est concentré dans les exploitations qui utilisent le PC, avec 66,8% du recensement total et 67.600 vaches ; les NPC totalisent 21.541 vaches, et 12.031 sont les fermes qui tirent parti des PC et des PPC. La densité du cheptel la plus élevée (2,4 vaches/ha SAU), correspondant au plus grand nombre de vaches par exploitation (60,1 vaches), se situe dans les exploitations qui utilisent les PPC. À l'autre extrême, se situent les fermes NPC, qui ont à la fois un taux de charge inférieur (0,9 vache/ha) et un nombre moyen de vaches inférieur (13,1 vaches). La vente de veaux est la principale activité économique des élevages de bovins à viande. Ainsi, les exploitations qui utilisent le PPC vendent en moyenne 42,4 veaux/an, celles qui utilisent seulement les PC, 20,5 veaux/an, tandis que les exploitations n'utilisant pas de PC déclarent vendre 9 veaux/an. En ce sens, 80,7% des exploitations vendent les veaux sous forme de '*pasteros*'[2], principal débouché pour les veaux à Cantabria.

Le Tableau 3 montre l'importance des pâturages dans le secteur bovin à viande. 94% de la SAU des exploitations sont des surfaces de pâturage, au même temps que les exploitations qui utilisent des PC possèdent le pourcentage majeur de SAU destinée à cet usage (98%). Malgré l'utilisation majoritaire du pâturage, la consommation de concentré dans l'hiver est plus élevée dans les exploitations qui utilisent des PC (2,2 kg/vache lactation/jour) que dans celles qui ne les utilisent pas (0,5 kg/vache/jour). Ceci est lié au fait que les pâturages communaux se trouvent dans des zones de plus grande hauteur et de climatologie défavorable, avec des hivernages plus longs et une qualité nutritionnelle inférieure qui conseillent des suppléments.

2. Veaux vendus au stade de la lactation et/ou nourris, également à base de pâturages, par opposition aux veaux engraissés. La dénomination *pasteros* fait référence au terme pâturages en espagnol (pastos).

Tableau 3. Variables (valeurs moyennes) par rapport à la base territoriale et variables liées à l'alimentation, en fonction de l'utilisation des pâturages communaux. 2016

Territoire et gestion alimentaire	NPC	PC	PPC	Total
SAU pâturages (% s. total SAU)	88,7 b	98,0 a	92,1 ab	94,0 *
Consommation de concentré (kg/vache lactation/jour)	0,5 b	2,2 a	1,3 ab	1,5***

Même note de bas de page que dans le tableau 2. Source: Données de l'enquête.

Le Tableau 4 montre de nouvelles différences entre les groupes d'exploitations étudiées en termes de titulaires. En ce qui concerne l'âge, les éleveurs ont en moyenne 51 ans, très semblable aux exploitations laitières (Vázquez et García, 2018). Ainsi, le groupe des exploitations de PC et de PPC a des éleveurs plus jeunes que le groupe des NPC et, en outre, les PC ont un pourcentage relativement faible, 40,3%, de titulaires à âge élevée (≥ 55 ans). Par ailleurs, les exploitations de NPC souffrent du manque le plus important de relève générationnel (68,4% des exploitations n´ont pas leur succession assurée) et d'une plus forte proportion de titulaires âgés (≥ 55 ans). Par conséquence, la viabilité potentielle des élevages de bovins de boucherie incombe aux exploitations qui utilisent le PPC, suivies de celles qui utilisent uniquement des PC.

Tableau 4. Variables (valeurs moyennes) liées à la personne titulaire, en fonction de l'utilisation des pâturages communaux. 2016

Titulaires et succession	NPC	PC	PPC	Total
Âge de l'éleveur/éleveuse	54,0	49,3	46,7	51,0 ns
Exploitant ≥55 années (% bétail)	61,8	40,3	31,1	48,5
Expl. sans succession (% s. total éleveurs/éleveuses ≥55 années)	68,4	44,7	29,5	56,3

Même note de bas de page que dans le Tableau 2. Source: Données de l'enquête.

Le Tableau 5 présente les variables économiques statistiquement significatives de l'étude. La dimension plus importante du bétail dans les exploitations qui utilisent PC et PPC les amène à obtenir des revenus plus élevés, comme l'indique la variable produit brut (PB), mais également des coûts totaux plus élevés (CT). Cependant, les fermes qui n´utilissent pas de PC, proportionnellement et par rapport au nombre total de vaches, ont un CT supérieur à celui des troupeaux de NPC. Ceci est lié à la dimension productive inférieure de ces exploitations reflétée, aussi, dans la MN négatif des exploitations NPC.

Tableau 5. Variables économiques (valeurs moyennes) dans les élevages de vaches à viande, en fonction de l'utilisation des pâturages communaux. 2016

Variables économiques	NPC	PC	PPC	Total
Produit brut (PB)[1] (€)	10.664 b	24.135 a	38.380 a	19.433***
Coût total (CT)[2] (€)	11.785 b	17.648 a	31.802 a	15.988*
Marge nette (MN)[3] (€)	(-1.121) b	6.487 a	6.579 a	3.445**

Même note de bas de page que dans le Tableau 2. Source: Données de l'enquête.

[1] Le produit brut est la somme des revenus de l'activité agraire (principalement, vente de veaux et subventions).

[2] Le coût total inclu les coûts fixes, coûts variables et amortissements.

[3] La marge nette est la différence entre PB et CT.

IV – Conclusions

Les variables analysées permettent de caractériser les élevages de bovins à viande, d'un point de vue territorial. Deux groupes d'exploitations importants ont été distingués :

– les plus nombreux et dynamiques, avec des propriétaires plus jeunes, des nombres de vaches majeurs et des densités du cheptel plus importantes utilisant des pâturages et des ports communaux et vendant un plus grand nombre de veaux, principalement destinés à les finir dans d'autres régions. Ce groupe est divisé entre les exploitations utilisant uniquement des PC et celles utilisant des PPC, plus intensives.

– l'autre moins nombreux, avec des propriétaires plus âgés et sans perspectives de succession, avec des dimensions de bétail plus petites et des pires résultats économiques qui n'utilisent pas des surfaces communales. Même si, à priori des exploitations ayant des terres propres sont censeés de montrer des charges plus élévées, cela n'est pas la réalité dans la région où la structure de la proprieté fait nécessaire l'appel aux communales si l'on veut obtenir des majeurs productivités. Aussi, ce groupe est conformé par des titulaires proches de la retraite qui ne visent pas un avenir pour l'exploitation et qui sont, clairement, touchées par le processus d'ajustement structurel intense dont on a parlé dans l'introduction.

À Cantabria, les pâturages et les ports communaux vertèbrent 60% des exploitations étudiées. Cela montre leur importance dans l'alimentation du bétail et dans la gestion du paysage. D'une part, le maintien des exploitations des NPC est certainement compliqué par sa faible viabilité, à la fois économique et démographique. Cependant, malgré les données économiques, il convient de noter que l'utilisation des PC est une caractéristique déterminante du secteur et, compte tenu de son importance, constitue une opportunité pour la promotion de systèmes de production extensifs basés sur les pâturages comme stratégie pour l'avenir du secteur à Cantabria.

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Effects of raising area and pasture type on carcass and meat characteristics of barbarine lambs

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Abstract. The aim of this study was to characterize the lamb meat of the mountainous areas of the Northwest "Djebel" of Tunisia. Lambs of Djebel group (D) were reared in a region characterized by mountainous terrain and soil unsuitable for crops, lambs grazed natural forests with dominance of woody species. While in the region of Bou-Rebiaa (BR) and Oueslatia (O), grazing pasture is based on herbaceous and lambs were supplemented with concentrate and hay. At the age of 6 months, lambs (12 from Djebel; 12 from Bou-Rebiaa and 11 lambs from Oueslatia area) were slaughtered. Lambs' slaughter body weight (SBW) was affected by the pasture type (25.8, 26.8 and 22.6 kg for Djebel, Bou-Rebiaa and Oueslatia region, respectively). Also, higher carcass weight and higher dressing percentage were recorded for lambs from Djebel and Bou-Rebiaa. Similarly, the skin, head and feet weights were higher for these groups; these organs are strongly correlated to the SBW which was higher for Djebel and Bou-Rebiaa regions. Similarly, higher ultimate pH and lower meat lightness (L*) were recorded for lambs from Djebel area. In conclusion, lambs grazing natural forests in the mountainous area presented similar carcass weight and SBW to those supplemented with hay and concentrate. Investigations on meat composition and eating quality are needed to characterize Djebel meat.

Keywords. Pasture type – Mountainous area – Lambs – Carcass characteristics – Meat quality.

Effets de la zone d'élevage et du type de pâturage sur les caractéristiques de la carcasse et la qualité de la viande des agneaux

Résumé. *Le but de cette étude était de caractériser la viande d'agneau des régions montagneuses du "Djebel" du nord-ouest de la Tunisie. Les agneaux du groupe Djebel (D) ont été élevés dans une région caractérisée par un terrain montagneux et un sol impropre aux cultures, des agneaux ont pâturé dans les forêts naturelles avec une prédominance d'espèces ligneuses. Alors que dans la région de Bou-Rebiaa (BR) et Oueslatia (O), les pâturages sont à base d'herbacées et que les agneaux ont été complétés avec du concentré et du foin. À l'âge de 6 mois, des agneaux (12 de Djebel, 12 de Bou-Rebiaa et 11 agneaux de la région d'Oueslatia) ont été abattus. Le type de pâturage influait sur le poids d'abattage des agneaux (25,8, 26,8 et 22,6 kg pour les régions de Djebel, Bou-Rebiaa et Oueslatia, respectivement). En outre, un poids de carcasse et un rendement commercial supérieurs ont été enregistrés pour les agneaux de Djebel et de Bou-Rebiaa. De même, les poids de la peau, de la tête et des pattes étaient plus élevés pour ces groupes; ces organes sont fortement corrélés au poids vif à l'abattage qui était plus élevé pour les régions de Djebel et Bou-Rebiaa. De même, un pH ultime plus élevé et une légèreté de la viande (L *) plus faible ont été enregistrés pour les agneaux de la région de Djebel. En conclusion, les agneaux élevés dans les forêts naturelles de la région montagneuse présentaient un poids en carcasse et un poids vif à l'abattage similaires à ceux recevant du foin et du concentré. Des études sur la composition de la viande et la qualité de l'alimentation sont nécessaires pour caractériser la viande de Djebel.*

Mots-clés. *Type de pâturage – Zone montagneuse – Agneaux – Carcasse – Viande.*

I – Introduction

Meat quality is becoming an essential concept of food policies. Thus, the development of systems for identifying and certifying the quality and origin of products, important criteria for consumers' choices, is nowadays needed. The producer may sort to employ production systems that provide acceptable carcass and meat quality (Warren *et al.,* 2008) and maintain healthy products for consumers. In Tunisia, during religious ceremonies, specific lamb types "Djebel" are distinguished by specific meat taste that consumers look for and appreciate. The aim of this study was to characterize the lamb meat of the mountainous areas of the Northwest "Djebel" of Tunisia in comparison to common meat.

II – Material and methods

Lambs of Djebel group (D) were reared in a region characterized by mountainous terrain and soils unsuitable for crops; lambs grazed natural forests with dominance of woody species. While in the region of Bou-Rebiaa (BR) and Oueslatia (O), grazing is based on herbaceous pastures and lambs were supplemented with concentrate and hay. The difference between the three sites was based on the distance to the sea. The experimental site D (36° 58′ 31″ North, 9° 04′ 51″ East) is 37 km away from the sea. The second site (BR, 36° 36′ 30″ North, 10° 10′ 18″ East) is 46 km from the sea. The third site (O, 35° 50′ North, 9° 35′ East) is 151 km from the sea. Lambs, lambs (12 from Djebel; 12 from Bou-Rebiaa and 11 lambs from Oueslatia area) were slaughtered at the age of 6 months.

All lambs were slaughtered in the abattoir of the INRAT. Before slaughtering, lambs were fasted for 12 h with free access to water. Animals were weighed just before slaughter (slaughter body weight, SBW). The head, skin, feet, full and empty digestive tract, red organs (heart, liver, lung and trachea), internal fats (omental and mesenteric) and the hot carcasses (HCW) were weighed using an electronic scale (Société Douik Balance, Sousse, Tunisia). The carcasses were stored at 4°C for 24 h. Then, cold carcasses were weighed (cold carcass weight, CCW). The dressing percentage was calculated as: DP=100 × CCW/SBW. The left half-carcasses were cut into six joints; all joints were dissected. Samples of *longissimus dorsi* (LD) muscle were taken for meat quality analysis.

The initial and ultimate pH was measured using a penetrating electrode connected to a portable pH-meter (HI 99163; Hanna Instruments, Romania) after calibration with two buffers (7.01 and 4.01). To determine the water cooking loss (WCL), meat samples were weighed (initial weight, Wi) and held in plastic bags and then immersed in a water-bath at 75°C and heated for 30 min until the internal temperature reached 75°C, which was monitored with thermocouple. Then, the bags were cooled under running tap water and blotted dry with paper towels. The cooked meat was weighed again (final weight, Wf). The WCL was calculated as 100 × (Wi –Wf)/Wi.

A Minolta chroma Meter CR-400 was used to measure color directly on the muscle surface, the colorimetric indices lightness (L*), redness (a*) and yellowness (b*) were recorded.

A one-way analysis of variance for the feeding system effects on the slaughter parameters, non carcass components and physic-chemical composition of meat using GLM procedure in SAS (1989) was applied. Then, the test Duncan was used to compare these effects (α=0.05).

III – Results and discussion

1. Rearing system

The mountainous areas of the Northwest "Djebel" of Tunisia is characterized by rugged, and soil occupied by natural forests unsuitable for crops. The herbaceous layer is almost absent throughout the

year (Gasmi, 2005) especially in summer when this experiment was conducted. The feeding system in this region is based mainly on grazing forest plants (*Phillyrea angustifolia*, *Erica arborea, Myrtus communis, Pistacia lentiscus*…). While, in Bou-Rebiaa (BR) and Oueslatia (O), grazing pasture is based on herbaceous and lambs were supplemented with concentrate and hay (Table 1).

Table 1. Characterization of main grazed species and diets chemical composition

	DM (%)	Crude Protein (% DM)
Phillyrea angustifolia	65.3	6.05
Arbutus unedo	44.3	5.04
Myrtus communis	49.4	5
Quercus suber	53.5	9.2
Quercus coccifera	72.0	7.8
Erica arborea	67.4	6.1
Erica multifida	77.9	5.81
Oat hay	91.5	5.0
Concentrate	93.4	13.9

2. Slaughter parameters

Slaughter body weight (SBW) of lambs averaged 25.8, 26.8 and 22.6 kg for Djebel, Bou-Rebiaa and Oueslatia, respectively, with significant differences between the regions (P=0.001). The feeding system based exclusively on forest plants in Djebel region originates the same SBW as that of supplemented lambs from Bou-Rebiaa region. Statistical analysis of the HWC and the commercial dressing percentage revealed significant differences (P <0.01) between the three areas in favour to the regions of Djebel and Bou-Rebiaa (Table 2). This difference is related to the fact that these parameters are strongly correlated to the SBW itself affected by the feeding system (Atti and Khaldi, 1987; Sañudo *et al.,* 1993; Mahouachi and Atti, 2005).

Similarly, previous studies showed that lambs grazing natural pasture reached slaughter age with a higher weight and less carcass adiposity than feedlot ones leading to an improvement of the quality aspects of products (Demeyer, 1992) and a reduction of feeding cost.

Table 2. Slaughter body weight, carcass weights and dressing percentages

Group	D	BR	O	SEM	P
SBW (kg)	25.8^{a}	26.8^{a}	22.6^{b}	0.39	0.001
HCW (kg)	12.3^{a}	13^{a}	9.01^{b}	0.24	0.001
CCW (kg)	11.8^{a}	12.2^{a}	8.75^{b}	0.22	0.001
CDP (%)	47.5^{a}	48.3^{a}	39.2^{b}	0.38	0.001

CDP, commercial dressing percentage; HWC, hot carcass weight; CCW, cold carcass weight; SBW, slaughter body weigh.

3. Non-carcass components and lambs' meat quality

The pasture type affected the red organs (Table 3). This result did not corroborate previous findings of Atti *et al.* (2004) showing that red cut-down organs are not affected by SBW. The head and feet weights were significantly affected by the raising area; as indicated above, these weights are strongly correlated to SBW, which was higher for D and BR regions. The finding of Devant *et al.* (2006) can explain partially our results especially when considering that D and BR are situated in the Tunisian humid area (abundant grass over the year). They documented that the intake of aro-

matic plants in pasture originated changes in the rumen fermentation profile, gut weight, and consequently, on carcasses weight.

Meat physico-chemical properties analysis (Table 4) showed that higher ultimate pH and lower meat lightness (L*) were recorded for lambs from Djebel area. This higher ultimate pH could be related to the conditions of breeding in terms of altitude, which were less stressful for the O animals reared on medium altitude pasture. Redness parameters, which strongly affect consumers' choices, were similar among groups.

Table 3. Non-carcass components weights

	D	BR	O	SEM	P
Head (kg)	1.6^{a}	1.6^{a}	1.5^{b}	21.9	0.01
Skin (kg)	4.43	5.26	2.67	873	0.5
Feet (g)	658^{a}	693^{a}	596^{b}	9.9	0.001
Red Organs (g)	688^{c}	1107^{a}	781^{b}	17.6	0.001

Table 4. Meat physico-chemical properties

	D	BR	O	SEM	P
Ultimate pH	6.01^{a}	5.95^{a}	5.55^{b}	0.04	0.001
WCL (%)	21.4^{b}	28.3^{a}	25^{ab}	0.98	0.02
L*	40.8^{b}	44.5^{a}	46.9^{a}	0.55	0.001
a*	15.7	16.33	15.05	0.34	0.33
b*	2.43^{b}	3.29^{a}	1.95^{b}	0.17	0.01

IV – Conclusion

Lambs grazing natural forests in the mountainous area presented similar carcass weight and SBW to those supplemented with hay and concentrate. Investigations on meat composition and organoleptic quality are needed to characterize Djebel meat.

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Small ruminants research and training needs assessment according to stakeholder's perspective in Andalusia (South Spain)

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Abstract. The current situation of small ruminants' sector in Spain is framed within a long process of restructuring associated with different national and international socio-political and economic challenges. In this framework, numerous studies confirm the importance of considering the opinions and perceptions of farmers to achieve all these challenges and highlight the weakness of agricultural research and training programs offered to meet farmers' demands for specific knowledge. This must be facilitated by policy programs where agricultural research and training institutions play a key role. In order to fulfil that gap, the Institute of Agricultural Research and Training in Andalusia (IFAPA) organized several focus groups with different farming and livestock sectors to identify their priorities on research and training to be included in its Sector Program 2018-2021. In the case of small ruminants and framed with the National project RTA2015-00070-C03-02, we proposed to identify and quantify small ruminants' sector real needs on research and training, to achieve greater productivity, competitiveness and sustainability. Thus, qualitative and quantitative methods were used during July 2018. Data were collected by a structured survey undertaken to 30 experts and a focus group organized with 25 livestock stakeholders (associations, cooperatives, research public institutes, universities, administration, etc.) related to the Andalusian livestock sectors. Results show that farmers have an integral view of their business by stating that they have to improve technological as well as commercial matters in order to be competitive.

Keywords. Research and training needs – Small ruminants' innovation – Livestock stakeholders' perceptions – Andalusia (Spain).

Évaluation des besoins en matière de recherche et de formation des petits ruminants selon le point de vue du secteur en Andalousie (Sud de l´ Espagne)

Résumé. *La situation actuelle du secteur des petits ruminants en Espagne s'inscrit dans un long processus de restructuration associé à différents défis sociopolitiques et économiques nationaux et internationaux. Dans ce cadre, de nombreuses études confirment l'importance de prendre en compte les opinions et les perceptions des agriculteurs pour relever tous ces défis et soulignent la faiblesse des programmes de recherche et de formation agricole offerts pour répondre à la demande des agriculteurs en connaissances et innovations spécifiques. Cela doit être facilité par des programmes politiques dans le cadre desquels les institutions de recherche et de formation agricoles jouent un rôle clé. Pour cela, l'Institut de Recherche et de Formation Agricoles d'Andalousie (IFAPA) (Espagne) a organisé plusieurs groupes de discussion avec différents secteurs de l'agriculture et de l'élevage pour identifier leurs priorités de recherche et de formation à inclure dans son programme sectoriel 2018-2021. Dans le cas des petits ruminants et dans le cadre du projet national RTA2015-00070-C03-02, nous proposons d'identifier et de quantifier les besoins réels du secteur des petits ruminants en matière de recherche et de formation, afin d'atteindre une meilleure productivité, compétitivité et durabilité. Pour cela, des méthodes qualitatives et quantitatives ont été utilisées en juillet 2018. Les données ont été recueillies par une enquête structurée réalisée auprès de 30 experts et un groupe de discussion organisé avec 25 acteurs du secteur de l'élevage (associations, coopératives, instituts publics de recherche, universités, administration, etc.) liés aux secteurs de l'élevage andalous.*

Mots-clés. *Besoins de recherche et de formation – Innovation des petits ruminants – Perceptions des acteurs de l'élevage – Andalousie (Espagne).*

I – Introduction

Small ruminant production represents an important productive sector in Andalusia (South Spain). The small ruminant's sheep and goat sector in Spain accounts for about 4% of Final Agricultural Production and 10.7% of Final Livestock Production. It is the most important livestock activity in Andalusia in terms of number of heads, sheep represent 13.9% (2,379,466) and goat gather 35.1% (1,100,012) of the national total with almost 3.5 million heads. In Andalusia in 2019 there were a total of 14,754 sheep farms (8,426) and goats (6,508) in its various modalities. Small ruminant breeding has also a high environmental value, since the breeding of indigenous breeds, especially goats, allows the use of many mountainous areas, which would otherwise remain untapped (Sayadi, 2012). Sheep and goats' activities in Andalusia are also a crucial sector for human activity. In case the industry declines, large areas will be adversely affected, leading to the loss of a culture that has survived virtually unchanged for centuries (Dubeuf and Sayadi, 2014).

Furthermore, the current situation of the small ruminants sector in Spain is framed within a long process of restructuring associated, among others, with the changes incorporated by the successive reforms of the Common Agricultural Policy (CAP), the greater liberalization and globalization of markets, the volatility of prices of raw materials and inputs, as well as the continuous changes of consumers demands towards multiple commodities and services. In this framework, numerous studies confirm the importance of considering the opinions and perceptions of farmers to achieve all these challenges; highlight the weakness of agricultural research and training programs offered to meet farmers' demands for specific knowledge (García *et al.,* 2018, Cruz *et al.,* 2019, Sayadi *et al.,* 2019); and the high importance to satisfy their needs on research and training to favour the innovation and their competitiveness (Cruz *et al*, 2018, Sayadi *et al*, 2019). This must be facilitated by policy programs where agricultural research and training institutions play a key role (Cruz *et al.,* 2018). To address these deficiencies, the Institute of Agricultural Research and Training in Andalusia (IFAPA) (Spain) organized several focus groups with different farming and livestock sectors to identify their priorities on research and training to be included in its Sector Program 2018-2021.

In the case of small ruminants and framed with the National project RTA2015-00070-C03-02, we propose to identify and quantify small ruminants' sector real needs on research and training, to achieve more productivity, competitiveness and sustainability.

II – Materials and methods

The information handled in this work is based on a mixed qualitative-quantitative methodology. Firstly, based on a detailed bibliographical review and the experience of the authors in research and training in livestock, in general, and the small ruminant sector, in particular (Ruiz *et al.,* 2011, Sayadi and Calatrava 2007), some research and training (R & T) topics have been identified and elaborated that could be considered priorities for the livestock sector. This review has been based on scientific articles, sector reports, etc. Subsequently, a structured questionnaire has been elaborated, basically consisting of two questions. The first asks for the importance and priority given to these identified research and training topics in the coming years according to the demands and needs of the livestock sector in general in Andalusia, and secondly, to develop specifically those specific R & T lines considered fundamental according to the livestock sub-sector needs in which the respondent is most involved and best knows (bovine, goat, sheep or beekeeping).

This importance and priority of the topics has been quantified in a scale valuation from 1: "not at all important, no priority" to 9 "very important, maximum priority". The questionnaire was sent during the month of May to 35 experts in Andalusian livestock of different profiles (5 advisers; 15 technicians of cooperatives and professional livestock associations, 5 administration technicians; 5 livestock researchers and trainers and 5 breeders), receiving responses from 30 of them. After

receiving this individual response, a livestock focus group was organised in Seville in July 2018 with the participation of 25 entities (associations, cooperatives, Public Research Bodies, universities, administration, etc.) related to the Andalusian livestock sector in order to identify their perceptions regarding the priority lines of research, training and transfer in the coming years.

Subsequently, throughout the focus group, each livestock sub-sector has been given the opportunity to reflect its opinion. Finally, the most important and priority research and training activities were debated, agreed and validated. In this work, the priorities for research and training in the coming years relating to the small ruminant sector are presented according to the opinion of the experts and taking into account the discussions and interventions throughout focus group.

III – Results and discussion

Table 1 includes the average values, in order of importance, of the values assigned by the experts regarding priority lines of research and transfer according to demands of the small ruminant sector in Andalusia, expressed on a scale from 0 (no priority) to 9 (maximum priority). We can see how all the topics of research and training have a value and priority higher than the middle point of the scale (>5).

The two lines identified by the experts with highest priority, with an average importance or priority greater than 8, in terms of research, transference and training, have been “Selection and improvement of autochthonous Andalusian breeds and the conservation of their genetic material” and the development of a mix of “New tools and methodologies for animal characterisation, sensory assessment and tenderness, milk or butcher yield, etc.”, with a great homogeneity (low typical deviation) of responses among experts (Table 1).

They also assigned great importance to matters, such as the “Improvement and modernisation of livestock facilities” and the “Improvement of efficiencies, products and processes in small ruminant’s farms”, with high average priorities of 7.98 and 7.76, respectively.

Experts are very aware of the importance of topics related to the market, commercialization channels and consumers. Specifically, the identification of more efficient ways of organizing the sector to improve marketing channels, contracts with large-scale distribution, short channels and development of proximity markets. Furthermore, the development and differentiation of new products and quality, and certifications based on territorial, environmental and sustainability attributes are also very important to increase productivity and competitiveness. Experts are also conscious about the importance of health management of livestock to maintain and improve the sanitary status of herds (i.e. goat sector: tuberculosis, paratuberculosis and contagious agalactia, etc.). “Obtaining and specifying basic technological packages for the improvement, selection and use of pastures and fodder and the preparation of animal diets” (6.75), and the “Use of new technologies in the field of pastoral livestock (GPS, drones...)” (6.69) as well as the “Development of technology and training to improve animal welfare, both on farms and in transport and slaughter” (6.64), are also mentioned by the experts as important topics to contribute to the satisfaction of research and training small ruminants needs. The “Experimentation in the use of by-products for animal feed” could be an interesting line (6.13) for the sustainable handling of waste and by-products of the farm and the territory. The above is in accordance with the approaches of bioeconomy and circular economy.

Experts are also interested (average importance between 5 and 6) in research and training programmes on: the “Evaluation and design of policies to promote the dissemination of innovations that favour the competitiveness and sustainability of livestock production systems, related agri-food companies as well as rural territory”, “Studies on the effects of globalisation on livestock farms”, “Appreciation of the profession of goatherd and/or shepherd and the evaluation of the action of pastoral

livestock in protected areas", as well as the "Valuation of positive externalities and ecosystem services linked to grazing practices in the extensive sector". The "Assessment of the environmental impact of small ruminant livestock (energy efficiency, greenhouse gases, biodiversity, etc.) and the design of promotion activities to increase social recognition of the livestock breeding activity is also required to improve and satisfy social demands and to improve livestock product prices at origin".

Table 1. Priority on research and training of livestock small ruminants according to experts' perspective

Research and training priorities	Average	Typical Deviation
Selection and improvement of autochthonous Andalusian breeds and the conservation of their genetic material.	8.35	1.09
New tools and methodologies for animal characterisation, sensory assessment and tenderness, milk or butcher yield, etc.	8.13	1.12
Improvement and modernisation of livestock facilities.	7.98	1.18
Improving efficiencies, products and processes in small ruminant's farms.	7.76	1.23
Search for more efficient ways of organizing the sector to improve marketing channels, and increase productivity and competitiveness, search for new marketing channels in origin and contracts with large-scale distribution.	7.56	1.21
Analysis of the potential of short channels and development of proximity markets.	7.34	1.23
Development of new products, differentiated quality, and certifications based on territorial, environmental, and sustainability attributes, typificity, etc. to improve visibility and consumption.	7.29	1.24
Health plan and study of the control of the diseases that generate the most losses in small ruminants' sector.	6.89	1.91
Obtaining and specifying basic technological packages for the improvement, selection and use of pastures and fodder and the preparation of diets.	6.75	1.48
Use of new technologies in the field of pastoral livestock (GPS, drones ...).	6.69	1.29
Development of technology and training to improve animal welfare, both on farms and in transport and slaughter.	6.64	1.26
Experimentation in the use of by-products for animal feed.	6.13	2.39
Evaluation and design of policies to promote the dissemination of innovations that favour the competitiveness and sustainability of livestock production systems, related agri-food companies as well as rural territory".	5.79	2.33
Studies on the effects of globalisation on livestock farms.	5.68	1.93
Appreciation of the profession of goatherd and/or shepherd and evaluation of the action of pastoral livestock in protected areas.	5.53	1.17
Valuation of positive externalities and ecosystem services linked to grazing practices in the extensive sector.	5.47	1.31
Assessment of the environmental impact of small ruminant livestock (energy efficiency, greenhouse gases, biodiversity, etc.). Promote recognition by society so that it translates into an improvement in the price of products at origin.	5.39	1.19

IV – Conclusions

Research and training play a fundamental role in the development of the livestock sector and directly influence the productivity increase and product quality, contributing, in addition, to the maintenance of environmental sustainability and the satisfaction of social demands.

The success of any innovation performed through research and training programs in the small ruminant sector is strongly influenced by local attitudes and environmental conditions as well as farmers' interest and involvement in topics covered. Several studies confirm the importance of considering the opinions and perceptions of farmers to translate research results and knowledge into practice. In this paper, the research and training needs of the small ruminant livestock sector have been identified and prioritised based on expert's knowledge. Subjects related to genetic improvement and conservation of autochthonous Andalusian breeds and animal characterisation new technologies, improvement of technical and economic efficiency, issues referred to market, new commercialization channel and product differentiation, the design of new mechanisms to value the pastures and shepherding activities, the internalization to breeders of the multiple externalities generated by small ruminants activities and the development of more efficient policies to promote the dissemination of innovations that favour the competitiveness and sustainability of small ruminant production systems and satisfy new social demands and concerns, are among other topics placed high on livestock farmers' list of training priorities. It seems that the interviewed stakeholders have an integral view of their business by improving technological aspects as well commercial means of reaching the market.

The research and training institutions have to include and re-orient their programs and sectorial strategies based on these findings to reduce the existing technological and adoption gap among the livestock farmers.

Acknowledgments

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Urban pastoralism as green infrastructure generator that provides important ecosystem services to the city

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Abstract. Pastoralism is a pattern of subsistence, that has survived in its close to original form even today in an increasingly urbanized environment. Marginalized by agriculture intensification, then industrialization and lately by the urbanization processes, this productive practice was restrained to marginal spaces and interstice of urban territory unexploitable by other activities. Its capacity of adaptation to harsh and changing conditions generated its resilience. The interdependency between the exploited environment, the shepherd and the flock along with the independence from urban infrastructure and mechanization permitted its survival despite its criticized low productivity, while transforming marginal land in productive and biodiverse spaces. Historically ignored by policies, a reconsideration of this practice is necessary, especially in the urban environment. In Romania, due to a combination of factors like rapid fragmentation of the rural and agricultural city's periphery by the urban sprawl phenomenon or the abandonment of agricultural exploitation of ancient socialist farm land located in the immediate proximity of the cities, the phenomenon of urban pastoralism developed in the last 2 decades in the urban interstices of nature. In France, the last decade has seen the evolution of eco-pastoralism in the city from experimenttion to institutionalization for ecological management of urban green spaces. While traditionally perceived as a rural practice, the pastoralism values the social, cultural, economic, ecological and agricultural dimensions of urban territories; with an appropriate recognition and management it could become an important tool for sustainable urban management. Its important role in supporting green infrastructure and local food systems is yet to be considered and integrated into urban policies

Keywords. Pastoralism – Green Infrastructure – Ecosystem services – Sustainable urban management – Local food system.

Le pastoralisme urbain comme générateur d'infrastructure verte qui fournit d'importants services écosystémiques à la ville

Résumé. *Le pastoralisme est un modèle de subsistance qui a survécu sous sa forme originelle jusqu'au présent dans un environnement de plus en plus urbanisé. Marginalisé par l'intensification de l'agriculture, puis par l'industrialisation et par les processus d'urbanisation récents, cette pratique productive était restreinte aux espaces et aux interstices du territoire urbain inexploitables par d'autres activités. Sa capacité d'adaptation aux conditions difficiles et changeantes a généré sa résilience. L'interdépendance entre l'environnement exploité, le berger et le troupeau ainsi que son indépendance par rapport à l'infrastructure urbaine et à la mécanisation ont permis son existence malgré sa faible productivité souvent critiquée, tout en transformant des terres marginales en terres productives et riches en biodiversité. Historiquement ignoré par les politiques, une reconsidération de cette pratique est nécessaire, surtout en milieu urbain. En Roumanie, en raison d'une combinaison de facteurs tels que la fragmentation rapide de la périphérie de la ville rurale et agricole par le phénomène d'étalement urbain, l'abandon de l'exploitation agricole d'anciennes terres des fermes socialistes situées dans la proximité immédiate de la ville, le phénomène du pastoralisme urbain s'est développé au cours des deux dernières décennies dans les interstices urbains de nature. En France, la dernière décennie a été synonyme d'évolution de l'éco-pastoralisme dans la ville, allant d'expérimentation à l'institutionnalisation de la gestion écologique des espaces verts urbains. Bien que traditionnellement perçue comme une pratique rurale, le pastoralisme valorise la dimension sociale, culturelle, économique, écologique et agricole des territoires urbains, et grâce à une reconnaissance et une gestion appropriée, il pourrait devenir un outil important de la gestion urbaine durable. Son rôle important dans le soutien des infrastructures vertes et des systèmes alimentaires locaux doit encore être valorisé et intégré dans les politiques urbaines.*

Mots-clés. *Pastoralisme – Infrastructure verte – Services écosystémiques – Gestion urbaine durable – Système alimentaire local.*

I – Introduction

In an increasing urban context, that marginalized both physically and culturally the agriculture practice, there is a need for a new approach to projects and policies to integrate a steady and productive vision. The agri-food system crisis at a global level encourage us to reflect on more sustainable, resilient and local adapted solutions of managing the territory, and therefore an emphasis on bottom-up initiatives, cultural and productive tradition, empirical transmitted know-how, the specificity of the socio-economic conditions, marginal, informal and spontaneous uses of land are gaining more attention.

The present paper aims to interrogate the city-nature paradigm and, therefore, the relation of man with his life environment from the perspective of ancestral productive practices. The human-animal-territorial relationship, in which the position of the animal (domesticated in this case) is intermediate, is explored through several filters: conceptually and practically.

This article that contains elements of my doctoral research argues that pastoral practice has its place in the urban and especially peri urban territory if the current way of practicing both in Western and Eastern Europe (as identified in interviews) is improved by a careful consideration of its strengths and challenges. Also, the hybridization of the two patterns of functioning could lead to a more resilient pattern of urban pastoralism.

The methodology of the study is based on both qualitative and quantitative data and includes bibliographic synthesis regarding the concept of urban pastoralism and the practice of extensive grazing, statistic data analysis and interviews with shepherds, authorities and other actors involved in this practice in Romania, France and Netherlands.

II – Urban pastoralism an oxymoron?

“Urban pastoralism” evokes a concept and a phenomenon, but also the clash between the two of them, that incorporates the nature-city paradigm.

“Urban pastoralism” represents an expression that designs the search for an ideal living environment (that defines the North American vision of the city) where nature and technology are harmoniously coexisting while approaching challenges related to urbanization, industrialization or ecological crisis and solving classical dichotomies like urban and pastoral (Machor, 1982).

As a pattern of subsistence developed earlier than agricultural practice, pastoralism coexists in its original form in a delicate equilibrium with nature, a fact that justifies the development of the concept of pastoral ideal. Today this practice can restore the biodiversity and productive feature of polluted, degraded and marginalized urban land. Mediating this classical antagonism between urban and pastoral or city /nature with strategy, policies, regulation, participatory methods can reduce the friction and improve the benefits generated by their coexistence.

The urban-rural interface is traditionally considered a space of friction between opposite contexts and functions but can also be a platform for a productive green infrastructure that would generate important ecosystem services like landscapes and biodiversity conservation, local food, preservation of cultural traditions and local identity. Multi-functionality of productive spaces and practices can enhance the quality of urban life (Artmann and Sartison, 2018). For example, ecological corridors recreated and managed by pastoralism can become, in addition to biodiversity reservoirs, also platforms for leisure, cultural and gastronomic activities.

III – The new phenomenon of urban pastoralism

As a phenomenon, urban pastoralism has not yet benefited from a crystallized understanding in scientific research (Bories *et al*., 2016). The interest of this subject is relatively obvious when the theme of urban agriculture has been explored from several angles over the last decade, except for livestock farming in the city. However, while current research, although schematically addressing all forms of maintenance of green spaces with animals, it focuses on the phenomenon of pastoralism that involves mobility, open spaces, corridors of transhumance, etc (Drăgănescu, 1998).

According to interviews with representatives of the structures involved in this practice in France and the Netherlands, the demand for maintenance of green spaces through the use of ruminants (particularly small ones) is constantly increasing and difficult to satisfy despite the efforts of intermediary organizations to train practitioners and put them in contact with potential clients.

In addition, these structures provide official data on this phenomenon and present the most relevant and complex arguments for understanding its interest.

The French association “Nature & Territory” created in 2009, interviewed in 2019 (http://intertrain-nature-territory.fr), which participates in the awareness, professionalization and observation of the eco-pastoral practice has tried to define and categorize different forms of pastoral practice, to serve as a basis for a broader discussion, which this paper does not claim to detail.

Pastoralism is a productive practice that coexists in harmonious conditions with the environment in which it unfolds, this interdependence constituting a fundamental characteristic. The flexibility of this activity is generated by several aspects: the correlation of the size of the herd with the availability of food sources, their accessibility even when they are remote thanks to the mobility of the shepherd and its influence, and its independence from infrastructure or the mechanization and the simplicity of the exploitation of resources generally available in nature. Thanks to this quality, pastoralism has adapted to all kinds of environmental, economic, cultural and socio-political constraints, and it can be described as resilient. This aspect justifies the survival of pastoralism in its original form in spite of having been considered as a retrograde livelihood, criticized and marginalized for its low productivity and has been in perpetual competition with other dominant types of production such as agriculture (particularly the intensive model), industrialization and the rapid and aggressive urbanization, associated with high consumption of space.

The shepherd must be a good observer of the environment, from the small lawn to the vast expanse of the transhumant territory, to find and properly manage the food resources, and the impact of the herd on pastures is beneficial (when grazing is practiced avoiding the land overburdening) in terms of biodiversity and interconnectivity (Meuret, 2010).

The selection of plant species consumed by animals is part of a process that maintains and develops the diversity of local flora. In certain regions of the world, pastoralism is exclusively reserved for this purpose, and when this function has disappeared, it is filled by mechanical means. The presence of animals (in a balanced proportion) in the grasslands improves soil fertility by various methods as animal waste (Bernués *et al*., 2011).

Transhumance corridors reconnect isolated areas, facilitate the transport of micro-organisms and insects with the help of animals, maintain open and accessible spaces, otherwise threatened by afforestation. So transhumance routes can therefore be described as ecological corridors.

If practiced in a sustainable way, pastoralism encourages flora and diversity of landscapes. Compared to large-scale grazing practices, pastoralism can be much closer to wildlife grazing patterns, mimicking the interactions and functional roles of natural ecosystems (CBD, 2010).

The creation of a multifunctional landscape is one of the most efficient types of green infrastructure in terms of ecosystem services, especially near or in urban areas subject to intense land use (Benedict and McMohan, 2002).

IV – Conclusions

The role of pastoralism in mediating and mitigating nature and city is currently considered and explored. From experimentation to a recognised urban function, the pastoral activity in the urban space expand due to the obvious ecosystem services delivered to the city.

The multifunctionalitygenerated by productive and cultural aspects of pastoralism, along with interconnectivity, created by flock mobility along ecological corridors, and biodiversity enhanced by the pastoral system, are transforming abandoned land in green infrastructure and generating important ecosystem services for the city.

Both approaches encounter difficulties due to frictions with urban functions and an elaborated vision of the coexistence of city and pastoralism must be developed in order to ensure its continuity.

Today a new formulation of harmony between city and nature is needed in order to improve the already existing widespread artificialized space (Niamir-Fuller *et al*., 2012). Rethinking the complex role (among which productive) of the animal in the urban space could significantly improve the global health of our living environment and therefore the quality of life in general.

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What issues prevent the development of sustainable food value chains for Albanian traditional mountains products?

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Abstract. The Albanian mountainous areas have local products with strong link to their specific origin. The current dynamics of the milk and meat value chains shows an asymmetric power that is hold by the dairies and the middlemen. The aim of this paper is to analyse what issues prevent the development of sustainable value chains for traditional mountains products. The use of a comparative analysis between the milk and meat value chain of a mountain territory is been made by analysing the strengths and weaknesses of the considered territory. The analysis is based on three stages: (1) analysis on the national milk and meat value chain; (2) analysis of the local livestock products value chain of the considered territory; (3) discussion and conclusion. Results shows that the current development of the milk and meat value chain does not position the local products in a niche market capable of engaging a virtuous circle for a good remuneration of the producers. This situation is not favourable for the development of mountainous products with specific characteristics and high reputation.

Keywords. Value Chains – Mountain Products – Albania.

Quels problèmes empêchent le développement de filières alimentaires durables pour les produits traditionnels de montagne? Evidences et perspectives de l'Albanie

Résumé. *Les zones montagneuses albanaises contiennent des produits locaux étroitement liés à leur origine. La dynamique actuelle des chaînes de valeur du lait et de la viande montre un pouvoir asymétrique détenu par les laiteries et les intermédiaires. Le but de cet article est d'analyser les problèmes qui empêchent le développement de filières durables pour les produits traditionnels de montagne. L'utilisation d'une analyse comparative entre la filière du lait et de la viande d'un territoire de montagne est réalisée en analysant les forces et les faiblesses du territoire considéré. L'analyse repose sur trois étapes: (1) une analyse de la filière nationale du lait et de la viande; (2) l'analyse de la filière des produits d'élevage locaux du territoire considéré; (3) discussion et conclusion. Les résultats montrent que l'évolution actuelle de la filière du lait et de la viande ne positionne pas les produits locaux dans un marché de niche capable d'engager un cercle vertueux pour une bonne rémunération des producteurs. Cette situation n'est pas favorable au développement de produits de montagne avec des caractéristiques spécifiques et avec une réputation élevée.*

Mots-clés. *Filières – Produits de Montagne – Albanie.*

I – Introduction

Agriculture is the most underdeveloped economic sector in Albania, and the integration of the Albanian agriculture in the European Union market is a challenge. The milk and meat value chains take an important place in the Albanian agri-food sector (MAFCP, 2014). The structuring of the national milk and meat value chains has affected the livestock production especially in the mountains areas. The majority of farms remain small and fragmented. They are facing major constraints such as poor physical infrastructure, lack of state support and a non-competitive market situation. In these areas, the livestock production is one of the main economic sources for farmers. Long economic transition and

demographic desertification creates nowadays a binding context to trigger local economic development dynamics. The national structuring of both value chains has changed the farming system in the mountain areas adapting them to the new context of free market. Recent research shows that Albanian consumer has strong preference for local products (Bombaj *et al.,* 2016). Despite this promising opportunity, farmers located in the mountains areas products propose mainly generic undifferentiated products to the consumers in the cities (Bombaj *et al*., 2018). Mountain food actors need to bring additional values to their production by creating product differentiation. Facing unfair competition the specific territorial resources (local products) can create added value for a better remuneration in the market (Barjolle *et al.,* 2007). This approach is based on the differentiation and valorisation of specific territorial resources (Barjolle and Sylvander 2002). In this context, the objective of this study was to respond to the following research question: a) what are the main issues that prevent the development of sustainable food value chains for traditional mountains products?

II – Methodology

The case study area is located in the most largest and marginalized municipality of the Korçë district: the municipality of Vithkuq. It is composed by 13 villages with a surface of 243.6 km^2. The study area corresponds to a coherent agropastoral zone with a long tradition of livestock production and high quality products. The area belongs to the Mediterranean, mountainous climate, characterized by relatively high temperatures during the summer and very low during winter.

The applied methodology is a collection of qualitative and quantitative, primary and secondary data. After data on general context were collected, a case study approach was used: documents, grey literature, and interviews for gathering primary data were done in the municipality of Vithkuq. As source of information on the local context, a combined mixed approach identifying value chains issues and traditional products market access was used (Bombaj *et al.*, 2016).

Our method was conducted in three stages:

- *Stage 1*. National value chain analysis. At the national level we combined several documents, including reports, databases, papers and other scientific such as interviews (in total 16) with rural development experts.
- *Stage 2.* Vithkuq value chains analysis. This stage was done in several steps: a) exploratory phase with literature research and choice of the study area; b) sample characterization: the farmers were selected by age, herd size, specialization (cattle / sheep / goat), but also according to an existing database from the Albanian Ministry of Agriculture; c) fieldwork phase in three steps: (step 1) interviews, and informal observations collected directly from the farmers (in total 33), (step 2) interviews and personal observations on the wholesale and the retail market in the regional market and stores in the capital of the country (in total 10), and (step 3) a workshop with farmers and local actors to discuss results.
- *Stage 3.* Results analysis. By combining results at the national and local level, a SWOT analysis is done in order to identify some key issues that prevent the development of sustainable food value chains.

III – Results and discussion

1. The national milk and meat value chain

The industry of milk processing grew in the early 1990s and nowadays at national level it has over than 400 processors, with several fully equipped dairies. According to official statistics, national milk

production reached 1.13 Million tons in 2014, an increase of 5.5 % since 2010. In 2014 about 51 % of the milk production has been sold in the national market (577 830 tons) or exported while the rest is used for self-consumption, consumption by animals or processed on the farm (see Fig. 1 below).

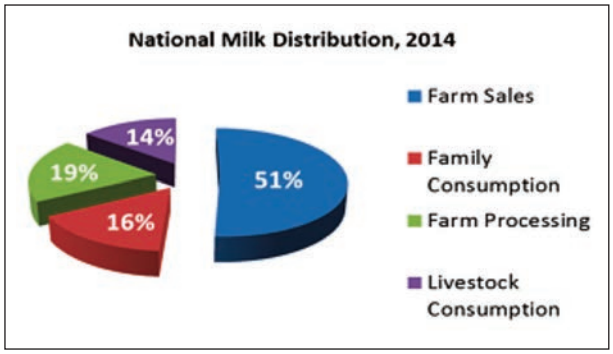

Fig. 1. Milk distribution in Albania, 2014 (Source: MAFCP, 2014).

An important part of the cow's milk is used especially for the manufacture of white cheese. Sheep's milk and goat's milk is also used to produce white cheese, but in smaller quantities and often the separation of white cheese from sheep's and goat's milk is not well defined. A very large part of the milk is consumed directly and untreated or not controlled. Because of tradition and the low purchasing power, consumers prefer to buy the cheap milk directly from farmers. From all the milk sold in the market only 40 % (231 132 tons) is processed by the dairy industry. The remaining 60 % (346 698 tons) is sold to the consumer directly by the farmers. Meat consumption in Albania is 43.4 kilograms per capita, but far from EU levels that are more than twice as high. In the value chain of meat, in addition to farms, there are also slaughtering and processing enterprises. There are only few operational modern slaughterhouses in the country. Animals are usually slaughtered on the farm or in some cases in local primitive slaughtering facilities on farms or in butcher shops. A different picture can be seen in the area of processing of meat. As local meat is limited and expensive, processing companies import the majority of their raw meat needed mainly from Brazil and Canada (INSTAT, 2014).

2. Vithkuq milk and meat value chains

Three dairies with a high geographical spatial dispersion were identified. Dairies collect milk from their nearest villages (Bombaj *et al.,* 2016). These dairies buy the majority of milk for processing it in cheese. The farms specialization is diverse in terms of milk and meat. The majority of farms are subsistence and they have low market access. In the Table 1 below a SWOT analysis for the milk and meat value chain is done. The presence of specialized farms and dairies is seen as an advantage. The agricultural practices of the farms and the primitive barns impair livestock productivity. But the consumer's preference for local dairy products remains high. This pushes farmers to specialize in the milk and/or the meat production. But the high land fragmentation results in low competitiveness and efficiency of production. Furthermore the lack of knowledge on modern production techniques, technologies and standards, the high price of animal feed and unproductive livestock breeds result in high costs of production for the farmers. These factors make impossible the exports of these products.

IV – Conclusions

In our case study, dairies and middlemen are important actors of the value chain dynamics. The current value chain dynamics do not sustain a certification process due to the high informality and low enforcement on food safety rules. Small farms lack investment potentials. Farmers have high production costs resulting in a low capacity to add value at farm level. They adapt individual strategies resulting in a low market power (Bombaj *et al*., 2018). Furthermore, small farm producers, of our case study, are not able to supply the market in sufficient quantities because their livestock and processing capacity is too low. Consequently, power relations and decision-making mechanisms within the stakeholders are key factors in the negotiation of the distribution of the value added at the supply chain level as well as at the territorial level. Contrarily, large farms, as in other case studies are predominantly market oriented, especially in the meat value chain. Anyway, further research is needed to understand how the increased demand for quality products has affected the local value chains for other products that are highly demanded by consumers.

Table 1. SWOT analysis for Vithkuq milk and meat value chains

Value chain	Strengths	Weaknesses	Opportunities	Threats
Milk	Private ownership of farms and dairies Very good tradition on milk production and processing	Mix farms with double orientation Low productivity of the mix farms	The annual increase of the milk production and the increasing regional and national demand for dairy products Increase in the number of farms specializing in the production of milk with more than 10 cows, more than 100 sheep and goats	Uncertainty over land rights. Lack of foreign direct investment in the area. Weak enforcement of laws regarding the quality standards
Meat	Large sizes of farms with modern stables Large farms have tractors and farm equipment for hay	The live weight of slaughtered animals is often much too low resulting in low profitability; the reasons are the demand for very young animals and the unavailability of cheap feed for the animals In most of the cases the small farms stables are in primitive conditions	Consumer preferences for local products Increase in the number of farms specializing more on meat production with more than 10 cows, more 100 sheep and goats	No export possible because of lack of enforcement of food safety laws Public rural infrastructure underdeveloped High cost production No market information system in place

Source: Surveys data and author's elaboration.

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Session 2

Meeting the challenge of climate change in Mediterranean agro-pastoral systems

Climate change impacts on Mediterranean small ruminant production systems and climate change mitigation options

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The Mediterranean basin is warming faster than the rest of the planet. Average annual temperatures are now 1.4 °C higher than during the period 1880-1899, well above current global warming trends, especially during the summer. Depending on the climate scenario and on the season, a rise in temperatures from 2 to 6 °C by 2100 is expected. High temperature events and heat waves are likely to become more frequent and/or more extreme. A reduction in summer precipitation has already been observed and model simulations indicate that such tendency should persist. For each degree of global warming, mean rainfall will likely decrease by about 4% in most of the region, particularly in the south. Heavy rainfall events are likely to intensify in all seasons except in summer.

Climate change in the Mediterranean basin has both direct and indirect effects on small ruminant systems. At the animal level, the increased temperature and radiation cause heat stress, which triggers behavioural and metabolic changes affecting animal health and welfare. Reproduction performance could be impaired by a reduced semen production and changes in the sexual activity of males, but also by a lower conception rate of females and lighter birth wight of lambs. Heat stress is usually associated with a low feed intake, and thus a reduced performance. Milk production could be reduced by 20-30%, with lower protein and fat concentrations and a reduction of coagulation properties in milk. Meat could develop an abnormal flavour, associated with a greater water holding capacity and a shorter shelf-life. In terms of feed supply, heat and water stress might modify the timing and length of plants' growing season. The productivity of forage and cereals in rainfed conditions is expected to decrease. Warming and the higher CO_2 concentration might decrease the nitrogen content of forage, but also favour nitrogen-fixing species (legumes), which could compensate for it. Thus, understanding and predicting the changing climatic patterns is increasingly important for Mediterranean farming sytems.

The simulation model SIMS-SR was designed, in the framework of the iSAGE project, to predict the performance of different small ruminant systems in a context of climate change. Inputs include : management strategy, animal genetics (breed), soil characteristics and climatic parameters. Outputs are: farm environmental performance (especially in terms of N and C losses), basic economic indicators and other attributes of sustainability. An example of simulation, for a sheep farm in Zaragoza, is presented. Under the current hypothesis of climate change, by 2100 the feed purchased is expected to increase by over 50% for forage (alfalfa) and over 25% for concentrate. As

1. This summary was elaborated by Magali Jouven on the basis of the presentation delivered by Agustin del Pardo in the 1st Joint Meeting of the FAO-CIHEAM Networks on Sheep and Goats and on Mediterranean Pastures, "Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas" (Meknes, Morocco, 23 to 25 October 2019).

a consequence, the economic return is expected to drop sharply, putting into question the economic sustainability or calling for a substantial increase in public subsidies. The question of adaptation of small ruminant systems to climate change deserves further research.

What about the contribution of Mediterranean small ruminant systems to climate change mitigation? Methane (CH_4) emissions are by far the main contribution of the livestock sector to global warming. A second noteworthy emission identified for Mediterranean small ruminant systems with the widely used IPCC (2006) is nitrous oxide (N_2O) at pasture, which discriminates against pasture-based systems. Fortunately, the emission factors at pasture have been recently re-considered, and with the new IPCC (2019) this component has become minor compared for example to CH_4 emissions of stored manure. Further credit would be given to pasture-based systems if, instead of normalising the warming effect of different greenhouse gases (GHG), the metrics would take into account the type and duration of natural recycling. In fact, the CH_4 produced by ruminants comes from the degradation of plant material and takes only 10 years to be converted into CO_2, which is taken up by plants, with an equilibrium between production and consumption at a global scale. Conversely, fossil fuel takes millions of years to be produced, and only a short time to be converted into CO_2, with limited recycling. Taking this into account could change the image of Mediterranean small ruminant systems, making them either marginal contributors (goat systems) or even net sinks of carbon (sheep systems, considering the uptake of CO_2 by natural pastures).

Different mitigation options for livestock and manure management have been provided by a recent report by FAO. They include: flexible grazing, alternative feeds (by-products, crop residues, alternative forages), alternative feeding practices (increasing number of meals, targeted supplementation…), landscape and stall developements (to provide shelter, water, shade…), choice of adapted animal and plant genetics, increased biodiversity in animal and plant components, novel reproduction techniques, manure treatments (anaerobic digestion, separation…). Such options need to be studied in the framework of an integrated approach taking into account the various components of the system, and a wide range of products and ecosystem services.

Sheep and goats production systems in the Mediterranean area are threatened by the severity of climate change. If they are to be part of action plans to become CO_2-neutral, then research and developement projects should: (i) incorporate the latest methodologies in GHG inventories, (ii) analyse pathways of changes with metrics that take into account the real warming effect of CH_4; (iii) consider together, in a synergic perspective, strategies of GHG mitigation and of adaptation to climate change.

Rehabilitation of Algerian rangelands: effects of *Atriplex canescens* plantation on biodiversity, soil physico-chemical parameters and soil surface elements

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Abstract. The 20 million hectares that covered the Algerian rangelands were the preferred area for breeding a livestock estimated at 24 million head of which 80% were sheep. Examination of desertification sensitivity and biomass maps showed that more than 55% of rangelands were classified as desertification-sensitive and the average animal load was 5.6 ha/head. To combat desertification and support livestock needs, the HCDS had launched a rehabilitation program through the introduction of a forage plant *Atriplex canescens*. This study was conducted in the department of Djelfa, on a 947 ha plantation, dealing with 4 age groups (2, 5, 10 and 15 years old). For each age group, 3 parcels were selected. In each parcel, 20 plants were pre-selected. For each foot we measured the height and the 4 cardinal rays. Three individuals per parcel were selected on the basis of their membership of the mean ± SE range over the five measured parameters. Three control shrubs, 9 shrubs per age class, 2,340 soil tests and 2,080 contact points were treated under R 3.5.2. It appeared that in 2 years we saw an improvement in the state of the soil surface, in 10 years we noticed an improvement in the carbon level in the soil as well as the diversity indices tested. For the 15-year-old class, an increase in the total nitrogen rate was underlined with a decrease in diversity indices.

Keywords. Desertification – Algeria – Rangelands – *Atriplex canescens* – Biodiversity.

La réhabilitation des parcours algeriens : efects de la plantation de* Atriplex canescens *sur la biodiversité, sur les parametres physico-chimiques du soil et sur les elements de la superficie du sol

Résumé. *Les 20 millions d'hectares que couvrent les parcours Algérien sont l'espace de prédilection de l'élevage d'un cheptel estimé à 24 millions de têtes dont 80 % d'ovins. L'examen des cartes de sensibilité à la désertification et de biomasse, montre que plus de 55 % des parcours sont classés sensibles à la désertification et que la charge animale moyenne est de 5,6 ha/tête. Pour lutter contre la désertification et subvenir aux besoins du cheptel, le HCDS a lancé un programme de réhabilitation par l'introduction d'une plante fourragère* Atriplex canescens. *La présente étude est menée dans la wilaya de Djelfa sur une plantation de 947 ha, renfermant 4 classes d'âges (2, 5, 10 et 15 ans). Pour chaque classe d'âge, 3 parcelles ont été retenues. Dans chacune des parcelles, 20 pieds ont été présélectionnés. Pour chaque pied nous avons mesuré la hauteur et les 4 rayons cardinaux. Trois individus par parcelle sont sélectionnés sur leur appartenance à la moyenne ± l'écart type sur les cinq grandeurs mesurées. 3 pieds témoins, 9 pieds par classe d'âge, 2340 analyses de sol et 28080 points-contact ont été traités sous R 3.5.2. Il ressort qu'à 2 ans on assiste à une amélioration des états de la surface du sol, à 10 ans à une amélioration du taux de carbone dans le sol ainsi que des indices de diversité testés. Pour la classe des 15 ans, une augmentation du taux d'azote total est soulignée avec une diminution des indices de diversité.*

Mots-clés. *Désertification – Algérie – Parcours –* Atriplex canescens *– Biodiversité.*

I – Introduction

Algerian rangelands cover 32 million hectares, 20 million being considered as steppic and 12 as presaharian. The predominant use of this vast swathe of land was livestock breeding, with an estimated number of 20 million heads, of which 80% were sheeps. Examination of desertification sensitivity and standing biomass maps, produced respectively by the General Forest Office (DGF) and the High Commission for Steppe Development (HCDS) showed that more than 55% of rangeland were classified as sensitive to highly sensitive to desertification, and that mean animal load was of 5.6 ha/ind. The carrying capacity of the Algerian steppe was thus of only 3.6 million heads.

To face this degradation, the Algerian state had planned and launched, since 1994 and by the means of the HCDS (Haut Commissariat au Développement des Steppes, High Commission for the Development of the Steppe), a vast program of restoration *sensu lato* named great steppic projects. Important means were attributed to the HCDS in order to control the desertification process, which had driven to an overall biological potential loss, and a breakage of previous ecological and socioeconomical equilibria (Hoppe *et al*., 2016; Kouba *et al*., 2018; Baranova *et al*., 2019).

Several restoration techniques had been selected among which fodder plantation, and several plant species had been introduced aiming at degraded rangeland restoration and fodder provision for a growing livestock. The choice of the restoration technique depended on the level of degradation of the area under consideration. Fencing was considered appropriate when the ecosystem was yet resilient and degradation minor. When a more degraded state was reached, fodder plantation was the chosen strategy. The criterion chosen by HCDS technicians was the Overall Vegetation Cover (OVC) with a threshold at 20%. When this parameter was below this level, fodder plantation was the chosen restoration technique. Among the fodder shrubs introduced in Algeria were *Atriplex nummularia*, *Atriplex glauca*, *Medicago arborea* and *Opuntia ficus-indica* but the species chosen for a massive plantation was *Atriplex canescens* (Pursh) Nutt. This species was chosen due to (i) its low production cost (3 Algerian Dinar per seedling), (ii) its resistance to cold and sand, (iii) its overall 1-year resumption rate of 130% (Amghar, 2012). We focused this study on (i) the facilitative effect of Atriplex canescens of contrasted ages on plant recruitment and its impact on (ii) soil chemical parameters and (iii) soil surface properties.

II – Materials and methods

The study took place on the Ain Chouhada plantation, 1225 m a.s.l., situated in the Southwestern part of the Djelfa department, at 80 km from the city. Its 947 ha had been planted in a few sequences from 1996 up to 2011, with the first aim to protect the village from sandstorms and thus to fix the sand. This aim had led to forbid any livestock to enter in the plantation since its beginning, whereas other plantation were usually rented after 5 years. This feature was an opportunity to study the long-term effects of plantation on soil and vegetation properties. The plantation was situated between 34°14'39'' and 34°17'46''N, 2°31'41'' and 2°21'35''E. Ain Chouhada is under a mean semi-arid bioclimate, with rainfall concentrated in fall and springtime. The minimum of rainfall and thermal maximum was in summer, typical feature of the Mediterranean climate (Daget, 1977). Mean annual rainfall (1971-2011) was 342 mm, and mean temperature for the hottest month and the same period is 33°C whereas it was of -0.1 °C for the coldest. The dry period lasted 5 months. Soils were xeric calcimagnesic with lime accumulation (Djebaili, 1978). Typical vegetation groups were dominated by *Stipa tenacissima*, *Artemisia herba-alba* and their degraded facies (Le Houérou, 1992).

Our aim being to characterize the effects of individual *A. canescens* on soil and vegetation properties, we selected in the plantation 4 age classes: 2, 5, 10 and 15 years since plantation. For each age class we sampled 3 plots, with a minimal distance between plots of 900 m, to control auto-replication. In each plot we chose 20 *A. canescens* individuals, the first randomly and the other on a

systematic distance of 20 m between plants on a square grid. The plantation was designed at an initial density of 1000 seedlings/ha, in rows separated by 2.5 m, with 4 m between each plant in a row. We measured on these 20 individuals the plant height and its 4 rays in the cardinal directions. We then chose in each age class 3 individuals for which the 5 biometrical parameters were within the mean+/-SD range, thus sampling on the most representative *Atriplex* in each age class.

For these 36 individual shrubs (4 age classes*3 plots*3 shrubs), we drew 4 transects from the shrub center toward each cardinal direction. For each transect we doubled the radius length observed and divided the total length in 60 equal intervals. These 60 points were divided in three subsets of 20 points, i.e. from the center on the shrubs 20 In points, then 20 Border points, and 20 Out points. On each of these 60 points we described (i) the vegetation using a vertical rod and noted each plant species contacts by the rod, *Atriplex* excluded; and (ii) the soil surface state. Plant species covers were calculated from these transects (240 points per *A. canescens*) and expressed as coverage percentage (Godron, 1968). For each of the 36 shrubs we calculated plant Species Richness (R) and Shannon diversity index (H'). Soil surface state had been quantified using the linear sampling technique (Daget *et al*., 1971). Three control areas were delimited in a plot neighbouring the plantation, where de degradation state was high, and similar to the state of pre-plantation. Three ghost *Atriplexs* were delimited and sampled, based on the 5- year old class dimensions, and sampled using the same protocol.

Soils were sampled in the superficial horizon H1. Ten cm diameter cores were sampled in the middle of each of the 3 compartments delimited in the transect (In, Border, Out). These 468 soil samples were 2-mm sieved and air-dried. Parameters measured on soils samples were organic matter determined following the Anne method (organic C measured by sulfo-chromic oxidation, ISO 14235) and total nitrogen obtained using Kjeldahl method (Bremner, 1996). We also calculated C:N ratio to inform soil mineralization status.

Data were, due to lack of normality, compared using non parametrical Kruskal-Wallis test (Zar, 1984) for diversity indices, soil chemical parameters and surface elements. All tests were performed using R 3.5.2 software (R Core Team, 2013).

III – Results and discussion

Floristic richness varies with Atriplex age: with respective values of 0 and 14 at 0 and 5 years, it culminated at 10 years with a value of 22, before decreasing at 16 at 15 years (Table 1).

Atriplex canescens introduction in Algerian rangelands, aiming at desertification control and fodder provision in order to cover growing livestock needs, was considered as a major mean of rangelands improvement (Amghar *et al*., 2008, Amghar *et al*, 2012). In their study in Tunisia, Jeddi *et al*. (2009) had shown that this species acts as a nurse plant, increasing soil nutrients and thus enhancing plant recruitment under and around them.

Shannon index follows a patterns similar to species richness (Table 1): at its lower in the control area (0.4) it reached its maximum in the 10-year age class (2.18). Plantations were more diverse and present a highest cover than in control areas ($p<0.05$). Both indices culminated in the 10-year age class. This can be acknowledged as an example of nurse effect: the shrub mitigated the harshness of the surrounding environment, either physical (moisture, nutrients) or biological (protection from livestock) and thus created a favourable environment (Orth et Girard, 1996), especially in our case for therophytes. This plant type benefited from the presence of the shrubs, and this effect, in the time span included in our sampling design, decreased after 10 years.

Table 1. Effect of Atriplex canescens age on floristic parameters. Values were Means +/- SE. Differences between age classes were tested by non-parametric Kruskal Wallis rank sum test, with a significance level as follows: * = p < 0.05, *** = p < 0.001. Different letters indicated significant differences between age classes

	Age class (years)					χ^2	P-Value
	0	2	5	10	15		
Diversity indices							
Floristic richness (R)	0.00 ± 0.00^{c}	14.11 ± 5.65^{b}	12.78 ± 2.73^{b}	22.56 ± 7.00^{a}	16.00 ± 5.72^{b}	16.31	<0.01
Shannon index (H')	0.40 ± 0.08^{c}	1.86 ± 0.30^{b}	1.97 ± 0.23^{ab}	2.18 ± 0.45^{a}	1.87 ± 0.39^{ab}	12.36	<0.05
Soil chemical parameters							
% Carbon	0.41 ± 0.29^{b}	0.51 ± 0.38^{b}	0.54 ± 0.40^{ab}	0.96 ± 0.56^{a}	1.10 ± 0.69^{a}	103.27	<0.0001
% total Nitrogen	0.01 ± 0.07^{c}	0. 01± 0.01^{c}	0.01 ± 0.01^{c}	0.02 ± 0.01^{b}	0.04 ± 0.05^{a}	236.3	<0.0001
C:N	29.73^{c}	47.06^{ab}	51.83^{a}	41.09^{b}	26.18^{c}	25.21	<0.0001
Soil surface elements (%)							
Coarse elements (CE)	14.17 ± 3.97^{a}	1.22 ± 1.72^{ab}	0.05 ± 0.15^{b}	0.52 ± 0.78^{ab}	0.71 ± 0.98^{ab}	15.14	<0.01
Litter (Lit)	0.00 ± 0.00^{b}	56.00 ± 29.64^{ab}	65.10 ± 27.89^{ab}	72.26 ± 23.80^{a}	65.02 ± 31.41^{ab}	9.24	<0.05
Glazing crust (GC)	85.83 ± 3.97^{a}	31.99 ± 27.74^{ab}	24.58 ± 19.42^{ab}	19.78 ± 18.32^{b}	25.08 ± 24.95^{ab}	9.18	<0.05
Sand (S)	0.00 ± 0.00	10.79 ± 8.56	10.27 ± 9.16	7.44 ± 6.77	9.20 ± 6.97	6.73	NS

Soil chemical analyses exhibited a highly significant difference in both parameters (C and N), and their ratio (Table 1). C and N reached their maximum in the 10 and 15-year age class, but C:N ratio was minimum at both ends of our time span, being maximum at ages 2 and 5-year. The increase in both C and N was expected after plantation, as a result of a litter input (and also rhizodeposition) from *Atriplex*. This improvement in soil chemistry enhanced soil macroscopical properties (structure, aggregation, infiltration) thus limiting the highly negative water runoffs.

The bell-shape pattern of the C:N ratio was less expected, especially the low ratio at 15-year. Soil C being quickly mineralized in these soils (Pouget, 1980), this feature can be linked to the N dynamics during *Atriplex* growth: the shrub could have an acquisitive strategy towards N during its first 10 years, beginning to restitute it at 15 years, thus enhancing C:N and promoting mineralization.

Soil surface elements exhibited a pattern consistent with vegetation parameters: elements unfavourable to seedling recruitment (CE and GC) were dominant in early age classes (from 100% in the control stage to 33.2% in the 2-year age class. The litter showed a significant increase during the first 10 years, and a slight decrease at 15-year, proportional with the shrub phytomass. The sand, even if the only non-significant soil surface state, presented an increase consistent with the role of sand-trap played architecturally by the shrubs. The fact that some proportion of CE and GC remained at the older age classes may be linked to residual runoff, thus questioning the opportunity of planting in a linear fashion.

IV – Conclusion

Our aim was to evaluate the impact of plantation age of an exotic American species (*Atriplex canescens*) on floristic diversity and some aspects of soil chemistry and surface. The plantation age had a significant impact on almost all the parameters measured. However, these differences were not univalent and some (litter, SR, Shannon) would lead us to recommend an opening of the plantation to grazing after 10 years, whereas other parameters (N, C, C:N) would increase this number to 15 years and maybe below. The somewhat conflicting objectives between fodder provision (reached early during *Atriplex* growth) and soil and diversity restoration (reached later) could lead to an “ageing island” management of plantations, with very long term exclosures.

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The prospects of pastoral sheep and goat dairy systems in the Mediterranean to cope with global changing: An analysis from the Corsican case

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Abstract. For millennia, small ruminants in the Mediterranean were associated with agro – pastoralism, as a set of practices to manage sustainably spontaneous resources on a wide variety of areas. Today, these practices like transhumance fascinate sustainable development experts and inspire them in terms of territorial resource management and biodiversity or know – how preservation. But, yet, and particularly in dairy and cheese production, pastoral components of the production systems have steadily declined as a technical model in favor of more specialized, more controlled, more intensive systems. Regarding the challenges and changes that livestock is facing at climatic, environmental, and social levels, can pastoralism help to reconfigure livestock systems, contribute to the agro-ecological transition and, if so, under what forms?

With the aim of contributing to the construction of a sustainable pastoral strategy for Corsica, we conducted a survey among pastoralists. We analyzed the organization of their breeding, their performances and expectations. The results of these interviews testify the diversity of the technical and organizational choices of pastoralists to match their activities with their personal projects; we show that these choices are often far from traditional representations of pastoralism. They can serve to build new technical models with new coherences based on qualified skills at individual and at territorial scales. This approach is compared and discussed to compare the situation in Corsica to other situations in the Mediterranean.

Keywords. Technical models – Production systems – Prospective – Dairy systems – Pastoralism.

Les perspectives des systèmes laitiers pastoraux ovins et caprins en Méditerranée face au changement global: Une analyse à partir de la situation en Corse

Résumé. *Pendant des millénaires, l'agro – pastoralisme en Méditerranée, auquel sont associés les petits ruminants, a permis de gérer durablement des ressources spontanées sur des terrains très variés. Il est à l'origine de pratiques qui fascinent aujourd'hui les spécialistes du développement durable et les inspirent en matière de gestion des ressources territoriale et de préservation de la bio – diversité. Pourtant, le pastoralisme ne cesse de reculer, en tant que modèle technique au profit de systèmes plus spécialisés, plus contrôlés, particulièrement en production laitière fromagère. Compte tenu des défis et des changements globaux que l'élevage doit aujourd'hui affronter, le pastoralisme peut-il contribuer à reconfigurer les systèmes d'élevage, et à la transition agro – écologique et si oui sous quelle forme ?*

Pour contribuer à la construction d'une stratégie pastorale durable pour la Corse, des enquêtes ont été réalisées auprès d'éleveurs se réclamant explicitement de pratiques pastorales. L'organisation de leur élevage, leurs performances, leurs attentes sont analysées et discutées. La diversité des choix techniques et d'organisation des éleveurs, de projets personnels et de modes de vie recherchés sont souvent très éloignés des représentations traditionnelles du pastoralisme. Les références produites peuvent servir à identifier de nouvelles cohérences basées sur des compétences qualifiées au niveau individuel mais également au niveau territorial. L'approche développée en Corse est mise en perspectives d'autres situations en Méditerranée.

Mots-clés. *Modèles techniques – Systèmes techniques – Prospective – Systèmes laitiers – Pastoralisme.*

I – Introduction

Corsica is a mountainous island located in the Central Western part of the Mediterranean basin. For millennia, pastoral activities associated to subsistence crop production have influenced the organization of the social life and pastoral culture keeps still in the minds and mental models of a large part of the society. We have chosen here the most common definition of pastoralism as a type of animal production based on the pasture of the spontaneous forage herbaceous and ligneous resources of rangelands. Pastoral production in Corsica was not specialized but dairy production and cheeses were an important part of these activities. A high percentage of lands could not be mechanized but grain could be produced up to high altitudes (Ravis – Giordani, 2001; Mercury, 2013). The progressive extinction of subsistence agriculture during the 20th century has contracted the space used by animals with a growing and general re-in forestation. One answer for animal production has been to settle in the few lowlands areas and continue to reduce the use of rangelands. Abandoning the high summer pastures has been also the consequence of the decrease of the number of breeders who in addition, prefer better conditions of living and working.

We consider this situation is not specific to Corsica, but it is characteristic of what happened in many Mediterranean regions where traditional pastoral systems have been marginalized, seen as archaic and doomed to disappear. Simultaneously, we observe in these areas, an important loss of biodiversity, a degradation of pastoral landscapes with erosion and scrub encroaching with an increasing risk of forest fires in less and less controlled territories. Meanwhile, everywhere, pastoral practices and know – how, appreciated typical products as cheeses fascinate more and more citizens, local stakeholders and development experts, who are inspired to manage territorial resources and to redesign technical systems to answer agro ecological transition issues (Dubeuf *et al*., 2016).

In Corsica, the Regional authorities have decided to make pastoralism one of the priorities for the development of the island to face the new challenges of global changing and because more lands could be available in pastoral areas (Collectivité territoriale de Corse, 2015). Without documenting their vision, they considered also that pastoralism would have high potentials; and they took several initiatives to define an operational pastoral strategy (Dubeuf and Sorba, 2018).

From the Corsican example, the objective of this communication is to identify at what extent agropastoralism could be a way to re design technical models of dairy small ruminant animal production and for what objectives.

II – Presentation of the regional approach in Corsica

1. Methodology

The approach chosen to help building an operational strategy for pastoralism in Corsica is participative, prospective and based on a documented diagnosis of the present situation of the breeders regarding the pastoral components in their systems. Our hypothesis is that we need to document the present situation to produce landmarks on the productions systems, the breeders' practices and expectations. It has been supported and this project is financed by regional authorities and based on 3 main activities:

– A review of the available information and existing references on pastoralism in Corsica; The documents published between 1970 and now have been reviewed and analyzed to give a general view of the dynamics of pastoralism in Corsica and the main observed changes.

– Several interviews in sheep and goat farms on their pastoral practices, the expectation of the farmers, and the main technical and economical results; at this stage,13 breeders were interviewed (10 during the study and 3 during a previous project), 7 with goats, 4 with sheep

2 with a mixed sheep and goat herd. All the breeders considered pastoralism is their type of animal production and they expressed how they see it. In the results a special focus was given on food autonomy and the interactions between the utilization of natural rangelands, their management and the distribution of external food (produced or bought hay and feed stuffs). The question of the pastoral products and the interactions between pastoralism, and the definition of pastoral products by consumers and prescribers have also been analyzed.

– The organization of thematic workshops involving the main actors of pastoralism in Corsica to share points of view about pastoralism and build a collective approach to define an operational strategy. The results of the first two activities will be mobilized during the ongoing workshops.

2. Results

A. The characteristics of the pastoral farms, their performances and practices

– **Localization of the farms, land structure available and pastoral practices:** Only three farms are located at an altitude above 500 m and two are in lowlands. Nevertheless, 11 from the 13 have no mechanized lands and most of them cannot produce hay or grain. Some of them cut some hay in far lands borrowed by colleagues but most of them buy hay (and mainly from the continent in the Southern France plain of Crau specialized in the production of high quality hay protected by a DPO). Most of the lands are rangelands with a mixed vegetation of shrubs and herbs associated or not to woods. Ten of 13 farms practice transhumance on summer pastures but only one process cheese during the transhumance what means that only dry, not milked animals go to summer pastures and the average duration of transhumance is below 2 months so significantly shorter than the traditional practices (4 months were reported). All the farms receive subsidies from the first Pillar of the CAP but only for a variable a part of the land they use.

– **Structure of the herds and production practices:** The average total livestock of the interviewed farmers is between 150 and 250 heads of sheep or goats except in one farm of 400 heads but located in the coastal plain. These results confirm the regional statistics showing that a majority of the bigger sheep herds are located in the plain with production systems based on natural or cultivated grasslands. In our case, the only herd located in the plain used natural and not irrigated lands and the farmer considers himself as following pastoral practices. The local sheep breed is the Corsican breed for which a rather efficient breeding scheme has been organized since 20 years. The goat breed is also mainly the old Corsican breed adapted to local conditions, but having neither an efficient selection scheme nor a collective organization, and many animals are crossed animals. Eleven of the 13 farmers are make cheeses at the farm although they sell a variable part of their milk to industrial cheese makers.

– **Technical performances and food efficiency:** The average milk yield per female is between 70 and 219 l/year for goats and 81 and 133 l/year for sheep. These performances are far below the average yield of both sheep and goats production systems in France but rather similar to the figures we observe in many other Mediterranean similar pastoral conditions. Otherwise, we cannot connect directly these yields to the amount of distributed hay and concentrate. While many references on the Mediterranean pastoralism consider that range lands can supply more than 65% of the total needs of animals, we observe here high variations on the pastoral autonomy indexes, between 22% and 75% but with an average under 50%.

Table 1. Main technical and economical results of the interviewed farms. NR: not recorded

Identification (Goats or Sheep)	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**S1**	**S2**	**S3**	**S4**	**GS1**	**GS2**
Altitude	<500m	<500m	<500m	<500m	<500m	<500m	<500m	>500m	>500m	lowlands	lowlands	<500m	>500m
Zip Code	202343	20226	20246	20250	20167	20232	20113	20250	20219	20167	20270	20167	20231
Age of the farmer (years)	40-55	40-55	40-55	<40	<40	<40	>55	>55	<40	>55	>55	40-55	>55
Size													
Total number of heads	230	249	302	240	245	182	207	133	208	260	430	G213/S232	G65/S82
Total female	170	203	234	160	220	142	160	113	169	210	360	G160/S200	G50/S66
Total male	20	8	25	10	15	18	35	4	29	40	60	G18/S20	G2/S11
Young does or ewes	40	38	43	70	10	22	12	16	10	10	12	G35/S12	G12/S5
Land used													
Mechanized lands	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	10	60	**0**
Range lands (ha scrubs and herbaceous without summer lands)	340	273	251	400	180	106	310	37	170	40	50	140	90
Dominant vegetation (herbaceous, ligneous)	L+H	L	L+H+Wood	L+W	L+H	L+H+W	L	H	L	H	H	L+H	L+H
Lands receiving subsidies (ha 1st Pillar)	NR	NR	NR	120	100	47	55	NR	65	20	NR	30	22
Purchase of hay (t/year)	20,8	8,75	13	30	30	15,5	8	15	26	13,2	77,62	17,5	20
Purchase of Concentrates (t/year)	17,9	13,9	29,2	47,5	30	7,2	13,4	20	15	37,5	139	23,5	15
Transhumance s (Y/N)	O	O	O	N	O	O	N	N	O	O	O	O	O
Duration of transhumance (Months)	2	2	2	-	2	2	-	-	2	2	2	2	2,5
Mountain cheese making (Y/N)	N	N	N	-	O	N	-	-	N	N	N	N	N
Production													
Total milk production (l/year)	18000	25000	26600	35040	32450	18000	17920	17967	15041	27920	39600	10800	16200
Milk production/present female	106	123	114	219	147,5	127	112	159	89	133	110	67,5/81	84,2/84
Milk production /milked female	138	171	133	241	161	181	140	161	105	145	114	112,5/135	114/105
Fecondity (%)	94	83	85	91	92	70	75	99	90	90	97	60/60	66/91
Food autonomy													
Food requirements A (UF)	76166	82289	100137	86270	107703	65840	69950	50195	69996	93236	130892	93026	46520
Distributed food intake B (UF)	34524	37490	25940	66525	60002	18653	18424	35002	41002	46375	87502	47205	28650
Estimated food intake by range lands (A-B/UF)	42642	44799	74197	19745	49299	47187	51526	15193	28994	46861	43390	45821	17870
Pastoral Autonomy Index (A-B/A*100)	54%	54%	**74%**	23%	46%	**72%**	**73%**	30%	41%	50%	33%	49%	38%
Economic results													
Feeding costs (€)	17280	16498	19400	31550	23200	8680	10148	13900	25995	21186	29200	11500	11500
Sold milk products (€)	-	-	-	14003	-	-	61200	18000	-	69998	42000	-	-
Cheese products (€)	45000	57500	45520	79322	42000	40500	-	-	48000	61200	12600	78570	58300
Meat products (€)	7500	8640	15120	4500	7560	4320	6000	-	1120	8050	-	25500	-
Total Products	52500	66140	60640	83822	49560	44820	67200		49120	139248	54600	104070	58300
Margin on food costs (€)	35220	49642	41240	52272	26360	36140	57052	4100	23125	118062	25400	92570	46800

From these data, we can assert:

- That range lands have the potentialities to provide a high amount of the forage supplies for the animals.
- That the control of pasture and pastoral management require high skills, know-how and references which have been lost in many cases.
- That there is great variety of rangelands and a good characterization and evaluation of their potentialities has to be carried out.

Thanks to a good valorization of the cheese and high milk prices, with good conditions to sell the kids (but not the lambs), and in spite of rather poor technical performances and high food costs, the pastoral farms can provide acceptable incomes for the farmers. But these results can be obtained as long as they receive subsidies from the CAP and they accept hard conditions of living. These conclusions agree with the conclusions of the typologies elaborated by the local regional chamber of Agriculture (Lafitte L-M., 2017, 2019; Idele, 2017; ILOCC, 2017).

These collected data are annual and for a given year. It would have been interesting to observe their interannual variability. The sanitary state of the flocks (specially for goats often highly impacted by paratuberculosis and other diseases) and the unpredictable and higher frequency of drought periods due to climate changing could affect the regularity of the performances.

B. Pastoral products: beyond stereotypes, foods to qualify

In many studies on pastoralism and its definition, the products are often forgotten. But defining pastoralism and its potentialities is also defining its products, how they are qualified. A recent research on this point (Sorba *et al*., 2016) has shown the total dissociation between the product, the food, and the conditions in which it has been produced. The selling points are generally minimalist and give few elements on the qualities given to pastoral cheeses. In main land France, cheeses are sold on purchase platform while in Corsica, direct sale is more common. In the first case, commercial stereotypes are dominant (natural conditions, the aesthetics of pastoral landscapes…) with a permanent reference to the use of raw crude milk; in Corsica, the use of crude milk is considered as usual and the cheese eaters associate them more to very general pastoral conditions (the breed, fantasy traditional practices). The market arguments are very weak in all cases and do not consider the pastoral production conditions. The diversity of cheese types is not related to the diversity of production systems.

III – Discussion: What levers for dairy pastoralism in Corsica?

In Corsica, like in many other Mediterranean situations, small ruminants pastoralism is related to dairy and cheese production. We know that in many mountain areas, we observe a renewal of pastoralism for sheep and meat cattle production systems. But, the results presented above and their variability show that the production systems are not yet fully stabilized. In these conditions, at what extent, considering the special zoo technical requirements of the animals, pastoralism could be also a solution for production systems including milk production? We observe that at a large extent forage autonomy is absent of the systems and presently the purchase of hay outside the island is the rule. In dairy systems, the distribution of hay and concentrates during critical periods (early lactation, late pregnancy) is necessary to control production and we know there is a lack of lands for producing hay near most of pastoral farms. The organization of a regional collective feed autonomy at the island level could be imagined as a solution to stick to agro ecological objectives. Besides, and this is another critical point, the total amount of distributed hay and concentrates could be reduced in many cases without impacting the productivity of the herds. The traditional know-how have been at a large extent forgotten and it should be necessary to produce the references and practices to reconquer and manage the pastoral spaces, to make them available and attrac-

tive to the animals. Paradoxically, because the price of the products and the market demand are high, the context is not very incentive to controlled management of feed complementation.

Pastoralism is no more an archaic and extensive type of animal production. It requires high technical multifunctional skills, innovation, and should be intensified in qualified labor. One way could be to acknowledge its ecological services in the several protected areas of the mountains of the island and follow agro ecological principles. Qualifying and certifying pastoral products according to the conditions could favor their acknowledgment by the society. Such dynamics would require a collective mobilization, a good coordination between the several actors, efficient extension services and a strong public support with a good capacity to define a clear strategy.

IV – Conclusion

The Mediterranean area has to face important challenges at a short term: deadline related to climate changing, water and food shortages and the future of animal production or the management and development of hinterlands are some of these challenges. We have shown here that the case of Corsica is very relevant to identify and face these issues. In spite of nostalgic visions, the rural societies will not be anymore what they were and the return to the past is neither possible nor desirable. For example, no young farmer would accept to give all his time to build stone walls and terraces. It is necessary to imagine new technologies, new know-how mobilizing for instance digital technologies, new knowledge to answer the present environmental and ecological challenges. To explore them and propose solutions for future, we plan to organize a prospective workshop and build collectively scenarios for future.

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Dynamics of livestock farming systems and adaptation strategies to climate and socio-economic changes in the Sétifienne semi-arid zone (Algeria)

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Abstract. The semi-arid highlands of Setif have been characterized by sheep farming and cereal cultivation for centuries. With the arrival of French settlers in the 19th century, cereal production became a priority in order to provide a growing metropolitan market. The integration of cereal farming and livestock production has since developed and resulted in the reservation of part of the sole for fodder crops and the creation of permanent grassland in wet areas (areas near rivers). Since independence (1962), public policies have induced, through the fixing of consumer prices and the subsidy of imported products such as cereals and milk, profound transformations within production systems. As a result, the traditional system, combining cereals and sheep, is currently undergoing major changes. This system is transformed from extensive agro-pastoral to a model in the process of intensification of livestock-mixed farming. The best-structured farms are geared towards valorizing the most profitable links in the production chain, while the majority of farms continued to practice cereals and livestock farming. The semi-arid farms have adopted a diversification strategy of agricultural and livestock activities with a view to improving their incomes and ensuring their sustainability.

Keywords. Dynamics – Breeding – Adaptation – Climate – Semi arid.

Dynamique des systèmes d'élevage et stratégies d'adaptation face aux changements climatiques et socio-économiques dans la zone semi-aride Sétifienne (Algérie)

Résumé. *Les hautes plaines semi-arides de Sétif se caractérisaient par l'élevage ovin et la culture de céréales depuis des siècles; avec l'arrivée des colons français au 19ème siècle, la production de céréales est devenue prioritaire pour pourvoir un marché métropolitain porteur. L'association céréales–élevage s'est depuis développée et a abouti à la réservation d'une partie de la sole aux cultures fourragères et à la création de prairies permanentes dans les parcelles humides. Depuis l'indépendance (1962), les politiques publiques ont induit par le biais de la fixation des prix à la consommation et la subvention de produits importés tels que les céréales et le lait, des transformations profondes au sein des systèmes de production. Par conséquent, le système traditionnel, combinant céréales et ovin, subit actuellement des mutations majeures. Ce système se transforme de l'agro-pastoral extensif vers un modèle en voie d'intensification de polyculture-élevage. Les exploitations les mieux structurées sont orientées vers la valorisation des maillons les plus rentables de la chaîne de production, alors que la majorité des exploitations ont continué à pratiquer la céréaliculture et l'élevage, Les exploitations en zone semi-aride ont adopté une stratégie de diversification des activités agricoles et d'élevage en vue d'améliorer leurs revenus et d'assurer leur durabilité.*

Mots-clés. *Dynamique – Élevage – Adaptation – Climat – Semi-aride.*

I – Introduction

The semi-arid zone of Setif has been characterized by pastoral farming and cereal cultivation for centuries. However, under the combined effect of climate change and policies implemented by the government since independence, the integrated cereal-sheep farming system has evolved into mixed crop-livestock farming. Many farms have adopted cash cropping and replaced sheep with dairy cattle that have gradually moved from humid coastal areas to the semi-arid high plains. Livestock production, a strategic and indispensable activity of farming is highly integrated with mixed cropping (mainly cereals) in smallholder farms (5 to 15 ha). Over 95% of the smallholder farms rear livestock that contributes significantly to the farm's income and secures it by enhancing the co-products of cereals (straw, stubble) and fallow. There is a steady decline in the average size of the farm, due to the fragmentation of agricultural land through inheritance. The reduction in farm sizes coupled with smaller herd sizes, water scarcity, erratic and low rainfall, as well as the effect of climate change, increase the risks and vulnerability of agricultural enterprises. In this context, the present work aims to document the dynamics of farming systems in a semi-arid region characterized by low forage production potential, as well as the strategies adopted by pastoralists for adaptation to climate change.

II – Materials and methods

1. Description of the study area

Setif is located in the high cereal plains of eastern Algeria. Its total area is 6504 km^2 or 0.27% of the national territory. Its altitude varies between 900 and 2000 m a.s.l. It is characterized by a continental climate with low and irregular rainfall (the annual average is 400 mm). It is subdivided into three zones according to the aridity gradient: northern semi-arid zone (NSZ), central semi-arid zone (CSZ), southern semi-arid zone (SSZ). Given its semi-arid characteristics, local agriculture is mainly based on sheep farming and cereal production, which occupies a large area estimated to be 180,765 ha. Milk production increased significantly from 66 million litre in 2000 to 248 million litre in 2012 (DSA, 2012).

2. Methodology

A total of 63 farms were surveyed to document the farm stucture, production systems and adaption strategies of livestock farmers to climate change, and to political and socioeconomic conditions. A detailed questionnaire was developed to collect information and the survey took place in 2013-2014.

These farms were selected from a long list based on the following criteria: *i*) farm size (UAA and livestock number), *ii*) dairy production *iii*) area cultivated with fodder crops. These farms are distributed over the 3 bioclimatic zones (NSZ, CSZ, SSZ).

III – Results and discussion

The typology established with the factor analysis (Figure 1) revealed that 70% of the sample studied consisted of small farms holding less than 10 head of cattle and less than 10 ha for the land base. This confirms the data of Sétif's Agricultural Services Directorate (80% of farms with less than 10 heads). This observation indicates the weak structure of these farms, which constitutes a risk to their sustainability.

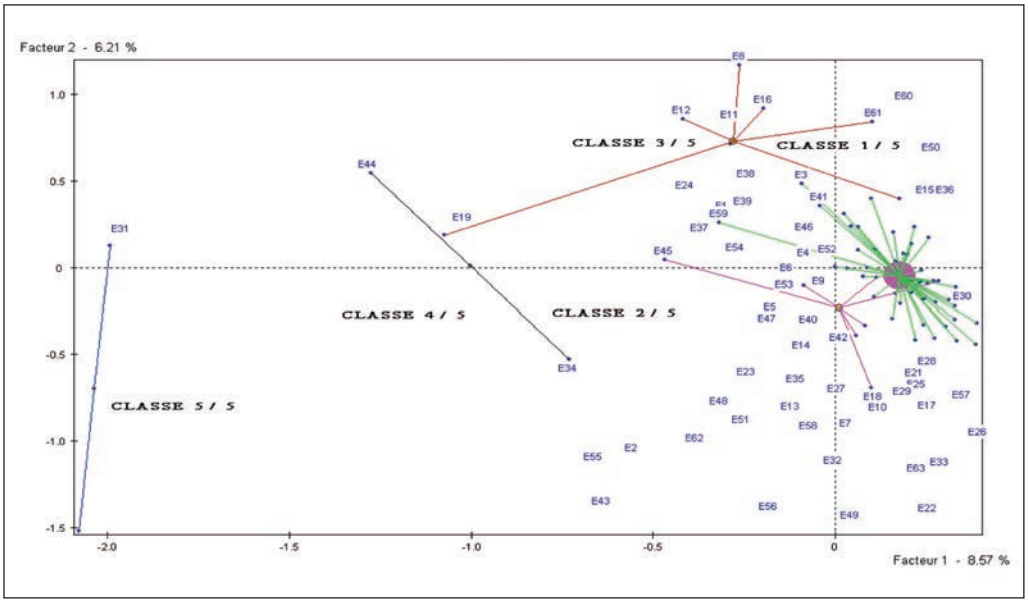

Fig. 1. Graphic of the groups identified by the MCA.

The analysis indicated that there are 2 types of feeding systems:

A) The grassland system: is practiced in the CSZ and NSZ farms, especially those located on the banks of the Wadi Boussellem, a zone favorable to milk production. The feeding is based on grassland grazing all year round. Concentrate feeds are distributed throughout the year with variations depending on the season and the physiological stage of the livestock (Madani *et al*., 2004).

B) The fodder system: is present in the SSZ farms that are poor in grassland resources. Feeding is based on cultivated fodder (irrigated forage, barley), straw, grazing stubbles and fallow land.

Fallow land is strongly integrated into the livestock feeding system, reflecting the low level of integration of forage crops in this region (Abbas and Abdelguerfi, 2005).

The feeding is essentially based on concentrate feeds because of the lack of off farm purchased cereal straw. The low level of integration of forage crops in rotations in the study area is attributed to the evolution of production systems towards cash crops that are deemed to be more water efficient than milk production.

To cope with the changes brought about by the climate as well as the agricultural policies of the government, the farmers of the region adopted adaptation strategies consisting of:

- Allocation of water to fodder used by dairy cows and to vegetable crop production (sources of income).
- Utilization of cereal crops by-products (straw, stubbles) and the adaptive management of cereal crops through their allocation to animals as feeds, in case of drought.
- Fattening of cattle, especially calves born on the farm.
- Exploitation of fallow land which significantly increases the contribution of the crops to the forage system of the farm.

IV – Conclusions

We can conclude that the emergence of dairy cattle farming in a semi-arid cereal-growing area is a strategy adopted to diversify and improve the income sources of family farms. In addition, this strategy ensures the sustainability of these farms, which are shrinking in size due to fragmentation of land by inheritance. The presence of dairy cattle on the farms of the semi-arid region could have positive consequences because it makes it possible to utilize cereal stubble and straw, ensuring their viability by generating additional income. The sustainability of livestock farming in the semi-arid cereal-growing zone depends primarily on the strategies to be developed by the farmers, in this case the conversion of the cereal cropping-fallow system to the cereal-forage / legume system. This allows the fodder system to be better integrated into both the cropping and the livestock systems.

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Holistic Management: an approach to increase pasture sustainability and mitigate climate change effects

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Abstract. Improving grazing management could increase soil carbon sequestration and other goods and services in grazing lands and contribute to increase pasture sustainability. The objectives of the study were to compare two grazing management techniques, one of them referring to holistic management. Nine plots, located in three farms in the Southwest of Iberian Peninsula under an Adaptive Multi-Paddock (AMP) grazing were compared with nine control plots of neighbouring farms with similar vegetation and soil and under a rotational stocking method. The analysed indicators were: Rangeland Health Index (RHI), plants richness and biodiversity, and soil quality like bulk density, total carbon and nitrogen, availability of phosphorous, calcium and potassium, microbial diversity and enzymatic activity. The results reveal better values of all indicators analysed in the AMP grazing plots in relation to control ones. Significant differences were found in percentage of ground cover, species richness, and availability of phosphorus and potassium ($P<0,05$). Although more studies are needed, these preliminary results show a trend to better health ecosystem and soil quality in the farms under AMP grazing. These findings highlight the importance of researching and implementing sustainable grazing managements to keep and restore grasslands thanks to ecosystem services generated by livestock, including carbon sequestration and climate regulation.

Keywords. Holistic management – Adaptive Multi-Paddock (AMP) grazing – Ecosystem health – Soil quality.

Gestion holistique : une approche pour accroître la durabilité des pâturages et atténuer les effets des changements climatiques

Résumé. *L'amélioration de la gestion des pâturages pourrait augmenter la séquestration du carbone dans le sol et d'autres biens et services dans les pâturages et contribuer à accroître la durabilité des pâturages. Les objectifs de l'étude étaient de comparer deux techniques de gestion du pâturage, l'une d'elles faisant référence à la gestion holistique.Neuf parcelles situées dans trois exploitations situées dans le sud-ouest de la péninsule ibérique sous un pâturage adaptatif à plusieurs enclos (AMP) ont été comparées à neuf parcelles témoins de fermes voisines présentant une végétation et un sol similaires et une méthode de stockage en rotation. Les indicateurs analysés étaient les suivants : indice de santé des parcours (Richland Health Index, RHI), richesse des plantes et biodiversité, et qualité des sols comme la densité apparente, le carbone total et l'azote, la disponibilité de phosphore, de calcium et de potassium, la diversité microbienne et l'activité enzymatique. Les résultats révèlent de meilleures valeurs pour tous les indicateurs analysés dans les parcelles de pâturage AMP par rapport aux témoins. Des différences significatives ont été observées en termes de pourcentage de couverture végétale, de richesse en espèces et de disponibilité de phosphore et de potassium ($P<0,05$). Bien que d'autres études soient nécessaires, ces résultats préliminaires montrent une tendance à l'amélioration de la santé des écosystèmes et de la qualité des sols dans les exploitations soumises au pâturage AMP. Ces résultats soulignent l'importance de la recherche et de la mise en œuvre de pratiques de gestion durable des pâturages pour conserver et restaurer les prairies grâce aux services écosystémiques générés par l'élevage, notamment la séquestration du carbone et la régulation du climat.*

Mots-clés. *Gestion holistique – Pâturage adaptatif multi-paddock (AMP) – Santé de l'écosystème – Qualité du sol.*

I – Introduction

Grazing lands represent the largest resource in the world, occupying about a half of the world's land area and providing a wide range of important economic, environmental, and social goods and services (Ronald *et al.,* 2010). Also they are a large repository of soil C because of their high C density and the vast land area they occupy (Schuman G *et al.,* 2002).

In a global context of land degradation and climate change, improved grazing management strategies could greatly increase soil C sequestration, while greatly improving their production potential and other environmental benefits (Schuman G. *et al*., 2002).

Holistic Management ^{TM} (HM), is a whole-farm management process relying on holistic-goal setting and adaptive decision-making. The grazing management, an Adaptive Multi-Paddock (AMP) grazing, try to mimic the intense yet brief grazing pressure of large herds, through high intensity grazing pressure followed by long rest periods (Savory and Butterfield, 1999; Stinner *et al*., 1997). In a farm, a grazing planning is implemented, with long recovery times (120-60 days) and short grazing periods (3 days by paddock), and livestock densities are higher than in traditional managemet.

There is controversy on the benefits of Adaptive Multi-Paddock (AMP) grazing and its role in ecosystem sustainability, and, to our knowledge, there is not any research carried out in Mediterranean context. Some researchers have concluded that even rotational stocking method offers no significant benefit over continuous stocking (Holechek *et al.,* 2000; Briske *et al*., 2008). While others show evidences in productivity and profitability and ecosystem health under Adaptive Multi-Paddock grazing (Teague *et al*., 2009b; Hillenbranda *et al.,* 2019).

Our objective is to study, in a Mediterranean context, the effects of an Adaptive Multi-Paddock (AMP) grazing on ecosystem health, plants richness and biodiversity, and soil quality.

II – Materials and methods

1. Farms and grazing management

This study was developed in three farms located in the Southwest of Iberian Peninsula, in Retamal de Llerena (Spain, 38º34' N, 5º49'W; 467 m a.s.l.), Elvas (Portugal, 38° 47' N, 7° 10' W; 190 m a.s.l.) and Campo Maior (Portugal, 39° 06' N, 7° 03' W; 259 m a.s.l.). The climate is Mediterranean, characterized by dry summers and high variability rainfall with an annual average of 450 mm.

The farms managed under AMP have an average area of 450 ha of agroforestry system (*Quercus Ilex*). The herds are composed of 1400 merino sheep's in one farm, and 100 and 250 angus cows in the others farms.

Since 2015 a Holistic Management has been implemented, under an Adaptive Multi-Paddock (AMP) grazing with relative high stocking density, with mean values of 25 Animal Units/hectare (AU/Ha), where one Animal Unit is equivalent a one mature, non-lactating bovine weighing 500 kg and fed at a maintenance level for zero gain. AMP is also characterized by using short grazing periods in each paddock, with mean values of three days and adequate resting periods during the growing season, with mean values that oscillate between 100 days when the plants growth is slow- autumn and winter- and 40 days when the plants growth is fast- spring-.

Closer farms were chosen as control, having similar soils, vegetation, livestock (cattle/sheep) and stocking rates. These farms followed a conventional management consisting in a rotational stocking method with lower stocking density, larger grazing periods and shorter rest periods.

2. Sampling and analysis

The sampling was carried out during the spring of 2018 in three plots per AMP farm and three in their respectively controls, in total nine plots under AMP grazing and nine control plots under a rotational stocking method.

In each plot the Rangeland Health Index (RHI) was measured according to Borreli *et al.* (2012). Also floristic inventories to determinate biodiversity and species richness were made in each plot identifying all species in 100 m^2. Three square of 1m^2 each were used to determinate the abundance of each taxon considering Braun-Blanquet scale (1979). Shannon-Wiener Index and Simpson's Index were calculate to determinate plant biodiversity.

Furthermore, two total soil samples were taken per plot, one under the canopy of trees and another outside the tree. The sieved soil samples (> 2mm) were divided in 3 aliquots, one was used to calculate bulk density and total carbon and nitrogen and phosphorus, potassium and calcium availability. The second was kept refrigerated until enzymatic activity analysis were done using Biolog Plate technique and the third aliquot was stored at -80 ºC for analysis of phospholipid fatty acids analyses (PLFAs) to determinate microbial structural and functional diversity.

For the statistical analyses, the SPSS Statistics v24 program was used. Student's T test was used to evaluate if there were significant differences among treatments.

III – Results and discussion

The RHI was higher in farms under AMP grazing, but with no significant differences respect to control farms. However, the biological indicator of percentage of ground cover was statistically higher in 10 average points (the score according to ground cover ranged from +20 to -20) in AMP farms in contrast to control farms. These results agree with Teague *et al.* (2011) that found that the percentage of bare ground was statistically significant lower on pastures under holistic grazing. Vegetation cover is likewise an important ecological indicator related to pasture sustainability as greater bare ground results in increased run off and soil loss.

In relation to plant biodiversity, no significant differences were found between treatments. However, farms under AMP grazing presented higher level of species richness in contrast to control plots, with mean values of 47,22 and 39,33 species respectively ($P < 0.05$).

Hillenbranda *et al.,* 2019 also found positive results in a holistic planned grazing (similar to AMP grazing) with bison compared to continuous grazing with cattle, including increase fine litter cover, herbaceous biomass, plant composition, plant importance value, and decrease in bare ground and improve water infiltration rate.

The nutrients and physical soil indicator measured (Table 1) were better under AMP grazing, but only the value of phosphorus and calcium presented statistically significant differences. In relation to enzymatic activity and microbial biodiversity in soil samples outside the tree higher values were found under AMP grazing, without significant differences (p= 0.875 and p = 0.088 respectively). Teague *et al*. (2011) found that land grazed holistically presented better soil quality in higher ratio of fungi and bacteria and higher contents of calcium, magnesium, and sodium.

On the other hand, Stanley *et al.* (2018) comparing the life cycle analysis (LCA), including soil carbon sequestration, in two different beef systems – AMP grazing and feedlot-finished cattle (FD) – suggest that AMP grazing has the potential to offset greenhouse gases (GHG) emissions through soil carbon sequestration, and therefore not only improving grazing management can facilitate carbon sequestration, but that the finishing phase could be a net carbon sink.

Table 1. Soil indicators measured, units and method applied and results

Soil indicators	Method/technique	AMP	Control
Bulk density (g/cm^3)	Steel cylinders (Coile, 1936)	1.52 ± 0.37	1.60 ± 0.40
Total carbon (%)	Dry combustion (Dumas method)	1.78 ± 0.66	1.48 ± 0.44
Total nitrogen (%)	Dry combustion (Dumas method)	0.22 ± 0.07	0.18 ± 0.06
Phosphorus (mg/kg soil)*	Colorimetry	89.82 ± 81.67	0.18 ± 0.41
Potassium (mg/kg soil)*	Flame spectrometry	1593.01 ± 877.36	915.60 ± 3344.99
Calcium (mg/kg soil)	Flame spectrometry	1098.57 ± 1203.97	750.04 ± 704.73

AMP: Adaptive Multi-Paddock grazing; Control (Soil samples taken outside the tree);
* Statistically significant differences P value < 0.05.

IV – Conclusion

Although further studies are going on, which means more farms and long-term trials, these preliminary results suggest that AMP grazing in a whole-farm Holistic Management can be a tool for improving environmental pasture sustainability and soil health and contributing to mitigate climate change.

Acknowledgments

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Evolution and transformation dynamics of rangeland in Moroccan north Atlasic plains and plateaux: Rhamna's case

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Abstract. Rhamna region is an agro-pastoral zone characterized by an arid climate. It is part of pastoral ecosystems classified as moderately degraded in Morocco. The objective of this research is to determine the dynamics of this ecosystem over time by integrating the effects of climate change. The dynamics of land-use change was apprehended by a study of multi-date remote sensing of satellite images (1987 and 2017). The diachronic study of land use in Rhamna shows a clear regression of pastoral areas in favor of cultivated land and often gives way to completely bare land. Critical regression of vegetation cover is mainly due to increasing pressure. But climate change has aggravated the situation in recent decades. Long-term analysis of climate data shows that one year out of two is considered agronomically dry. Other environmental degradation factors stem from current changes in pastoral society. Indeed, the last sequence of dry years has led to a massive use of concentrate feeds. Cereal cultivation, although not a new phenomenon in the region, has reached alarming proportions.

Keywords. Rhamna – Pastoral area – Degradation – Climate change – Vegetation cover.

Dynamique d'évolution et de transformation des parcours dans les plaines et plateaux atlasiques du Nord marocain : le cas de Rhamna

Résumé. *Rhamna est une zone agro-pastorale caractérisée par un climat aride. Elle fait partie des écosystèmes pastoraux classés comme moyennement dégradés au Maroc. L'objectif de cette recherche est de déterminer la dynamique de cet écosystème au fil du temps en intégrant les effets du changement climatique. La dynamique du changement d'occupation du sol a été appréhendée par une étude de télédétection multi-date d'images satellitaires (1987 et 2017). L'étude diachronique de l'utilisation des terres à Rhamna montre une nette régression des zones pastorales en faveur des terres cultivées et cède souvent la place à des terres complètement nues. La régression critique du couvert végétal est principalement due à la pression croissante. L'anthropisation est établie depuis longtemps, mais le changement climatique semble avoir aggravé la situation au cours des dernières décennies. L'analyse de long terme des données climatiques montre qu'une année sur deux est considérée comme sèche sur le plan agronomique. D'autres facteurs de dégradation de l'environnement découlent des changements actuels dans la société pastorale. En effet, la dernière séquence d'années sèches a conduit à une utilisation massive d'aliments concentrés. La culture de céréales, bien que n'étant pas un phénomène nouveau dans la région, a atteint des proportions alarmantes.*

Mots-clés. *Rhamna – Zone pastorale – Dégradation – Changement climatique – Couvert végétal.*

I – Introduction

In Morocco, rangelands are the scene of a negative and continuous ecological imbalance with an inexorable degradation resulting from overgrazing, clearing and cultivation (Berkat and Hammoudi. 1989, El Koudrim *et al*., 2003, El Koudrim *et al.,* 2014). This resulted in low production and declining forage quality.

Rhamna is an agro-pastoral zone characterized by an arid climate. It is part of pastoral ecosystems classified as moderately degraded to degraded (Berkat *et al*., 1992). But currently, these range-

lands are in an increased degradation that places them rather among the most degraded ecosystems. Unfortunately, much information is lacking concerning this degradation and the resilience capacity of rangelands.

Currently, there is a growing interest in understanding the interaction of climate change and agricultural production and this is driving a significant amount of research (Aydinalp and Cresser, 2008). Moreover, there is still limited research regarding the impacts of climate change on livestock production (IPCC, 2014).

The objective of this research is to determine the dynamics of the Rhamna ecosystem over time by integrating the effects of climate change on land-use change and grazing evolution.

II – Materials and methods

Rhamna is part of the greater Marrakech-Safi region. Its area is over 550.000 ha, with a population of 350.000 inhabitants, 60% rural. The climate is arid with an average rainfall of 250-300 mm. Rhamna is classified as an agro-pastoral system.

The study of meteorological drought plays a key role in any program to combat the effects of climate change on agriculture (Rojas-Downing *et al*., 2017, Dong *et al*., 2011). Therefore, in a long-term strategy program, decisions should be based primarily on the analysis of meteorological variables and agricultural production. Climatic data used in this study was retrieved from the meteorological station of Benguerir. The data is verified, sorted and added into database. The analysis of climatic variability is carried out by the study of long climatic series (30 years).

The potential indicators used in the climate study are aimed at establishing a comprehensive system of long-term climate change. However, taking into account the specificity of the study area, a limited number of indicators can be proposed. For this work, we used the Precipitation Standardized Index (Mckee, 1993). In fact, several indices are developed to characterize drought, the most used are Standardized Precipitation Index (SPI) (Mckee, 1993). Our objective is to characterize agronomic drought, so we used SPI for 3 months (Barakat and Handoufe, 1998).

Vegetation is a major environmental parameter that, through its physical and floristic structure, can be used for the environmental identification and characterization of the agro-ecological zones (Berkat *et al*., 1992). The study focuses on environmental stratification and vegetation characterization and land-use comparisons between 1988 and 2017 in the Rhamna region using remote sensing. Two free Landsat images downloaded from USGS (US Geological Survey, http://glovis.usgs.gov/) were processed and analyzed using GIS software. Several algorithms have been applied to highlight the land use and its evolution between the two dates. The identification of land cover layers for 2017 was done by a supervised classification based on field data.

III – Results and discussion

1. Climatic study

In Rhamna agro-pastoral zone, drought contributes in soil cover reduction and lands deterioration and consequently in increasing soil vulnerability to erosion.

The results show that the annual precipitation average is about 230 mm/year. The minimum is 99.4 mm recorded during 2000/2001 and the maximum is 396.4 mm during 1996/1997.

We can also note, alike the majority of arid zones (Benzarti *et al*., 2001), a wide distribution of annual precipitations (Fig. 1) with 34% of coefficient of variation. However, the trend remained stable.

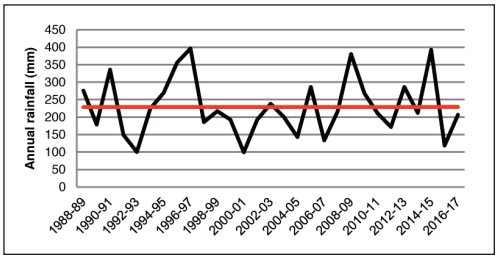

Fig. 1. Variability of annual rainfall and linear trend.

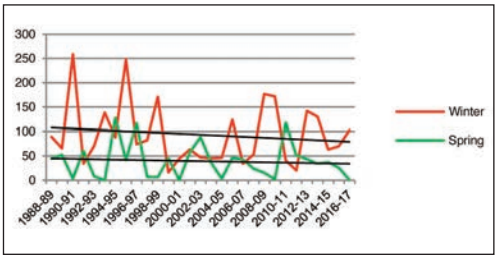

Fig. 2. Seasonal precipitations trend.

For the annual plants, spring is also a very critical period. A water deficit during this period, which corresponds to the end of a vegetative stage, would have consequently a reduction of the growth and a decrease in forage biomass. Indeed, a linear relation was established between rainfall, in particular the effective rain, and herbaceous biomass (Grouzis and Albergel, 1989).

For cereals, spring is the period of grain filling stage, so water deficit in this period would have a very significant reduction in cereal production. Definitely, cereal cultivation in this region is not justified on the agronomic and economic perspective.

Regarding the Standarized Precipitation Index (SPI), results show that during the last decades, half of years were dry (Fig. 3). Furthermore, the value of the drought index proves that 1992/1993 and 2015/2016 are the driest years during this period.

The monthly comparison of rainfall between dry years and the average of the series shows that the decrease in the rainfall occurs in the middle of the growing season and worsens in January, February and March. Similarly, there is a very significant reduction in precipitation in September (Fig. 4). It is therefore clear that the rainfall deficit during the years of drought will have a negative impact on soil cover.

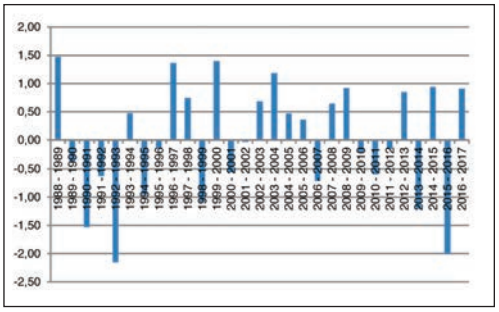

Fig. 3. Variability of SPI index in Benguerir station.

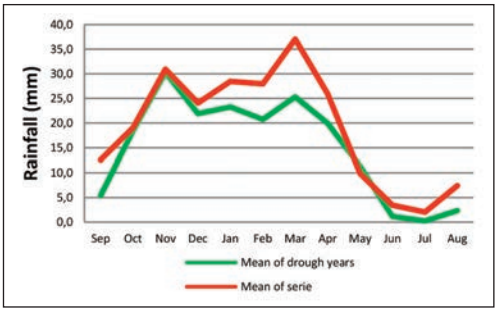

Fig. 4. Monthly rainfall in drought years and mean of the series.

2. Rangeland dynamic changes

For the assessment of change between 1988 and 2017, the study was based on the main land use strata, namely: forest, shrubs, rangeland, cropland, and bare soil and uncultivated areas.

Results obtained from satellite image processing, ranging from lean data to exogenous data, highlighted changes in the major classes of land cover. It is noted that the evolution of the environment is generally regressive. As a result, rangeland was decreased by 26%, shrubs by 17% and forest by 5%. On the other hand, crop land was increased by 20% and bare soil and uncultivated areas by 30% (Fig. 5).

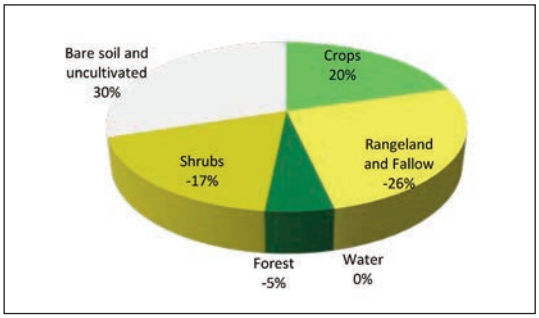

Fig. 5. Soil cover changes between 1988 and 2017.

These different changes in land use can be explained by simple shifts from one stratum to another. Indeed, rangeland, forest and scrub are recovered as cropland and bare soil and uncultivated areas. Nevertheless, the analysis of the matrix of changes shows that the contribution to change can occur simultaneously from several strata (Table 1).

Table 1. Matrix of changes in soil cover between 1988 and 2017

Land use class (2017)		Land use class (1988)						
		Crops	Rangeland and fallow	Water	Forest	Scrub and shrubs	Bare soil and uncultivated	Total
Crops	ha	10,811	90,115	3	13,033	5,882	5,230	125,076
	%	39	26	0	38	6	13	23
Rangeland and fallow	ha	11,041	139,212	0	2,076	59,030	6,251	217,611
	%	40	40	0	6	57	16	39
Water	ha	0	3	1,391	19	0	0	1,413
	%	0	0	88	0	0	0	0
Forest	ha	1,289	5,358	9	2,051	79	833	9,620
	%	5	2	1	6	0	2	2
Scrub and shrubs	ha	104	8,485	1	4,511	109	1,802	15,012
	%	0	3	0	13	0	4	3
Bare soil and uncultivated	ha	4,257	101,064	179	12,836	39,014	26,125	183,475
	%	15	29	11	37	37	65	33
Total (2008)	ha	27,502	344,239	1,582	34,527	104,115	40,242	552,207

Thus, the main changes observed in land cover between 1988 and 2017 are summarized as follows:

- Forest: the spaces assigned to this level are distributed among all the other strata. Thus, only 6% of the area in this class remained stable, while 38% was converted to cropland, 13% to shrubs, 6% to rangeland and 37% completely disappeared, leaving room for bare soil.
- Scrubs: Less than 1% of the area of this stratum remained unchanged. The remains were severely degraded to rangeland (57%) or disappeared completely by clearing (37%) or by cultivation (6%).
- Rangeland: this class has retained 40% of its area. Most of it disappeared to give bare soil (29%) and cropland (26%). Only 5% regenerated by reforestation and planting;
- Cropland: In general, this area has increased by 20% and 39%. The increase of these areas is due to the loss of rangeland (40%) and forest 5%. We also note that 15% was recovered from the bare soil.

– Bare soil and uncultivated: This class represents most of the area of Rhamna. It represents respectively 7% and 33% of this space in 1987 and 2017. These spaces have increased by 30% between these two dates. Most of it remained unchanged (65%), 16% comes from rangelands and 13% from cultivated land.

IV – Conclusion

The critical regression of the vegetation cover is due first to the growing pressure over the resources that has been in place for a long time, but climate change has worsened the situation in recent decades. The analysis of the current state of vegetation and environment shows a general tendency towards degradation.

In fact, the long-term analysis of climate data shows that one year out of two is considered agronomically dry. We would therefore find it difficult to support the hypothesis of a cyclical drought to explain the advanced level of degradation of the pastoral environment and which is rather the final stage of a long-standing process in which drought occurs only as a catalyst element.

Other factors of environmental degradation derive from the current changes in pastoral society. Indeed, the last sequence of dry years has led to massive use of concentrate feeds. Cereal growing, without being a new phenomenon in the region, has taken alarming proportions.

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Phytomass estimation of Moroccan rangeland using Sentinel-2 satellite indices and *in situ* biomass measurements

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Abstract. The monitoring of fodder production in arid and semi-extensive rangelands of Morocco is an essential component of livestock management. An accurate estimate of rangeland phytomass information is required for supplementary feeding leading to sustainable use of rangeland resources. The objective of this study is to test several vegetation indices resulting from remote sensing to propose the most appropriate vegetation indices for phytomass estimation of Moroccan rangelands. Field data, collected during spring 2018 in the Eastern region of Morocco, and eight vegetation indices (ARVI, DVI, IPVI, MSAVI, NDVI, RVI, SAVI and TSAVI) obtained from three Sentinel-2 satellite images acquired in April 2018 are used. Correlations between measured phytomass and each of these vegetation indices were performed to identify the best estimator. The results showed that rangeland phytomass ranged from 0.02 to 4.71 tons with an average of 0.84 tons per hectare in the studied site. Vegetation indices highly correlated with measured phytomass are ARVI, IPVI, NDVI, RVI and SAVI. Also, the results showed that polynomial models were better than linear ones. The best model of phytomass estimation was RVI followed by NDVI with a coefficient of deterimination, R^2, of 0.84 and 0.82, respectively.

Keywords. Biomass – Vegetation index – Pasture – Remote sensing – Eastern Morocco.

Estimation de la production fourragère des terres de parcours des Hauts plateaux de l'Oriental à patir des indices de télédétection

Résumé. *Les terres de parcours des Hauts Plateaux de l'Oriental constituent un appoint important à l'alimentation du cheptel ovins et caprins. L'estimation de la production fourragère de ces terres de parcours est utile pour les gestionnaires des espaces pastoraux. L'objectif de cette étude est de tester plusieurs indices de végétation issus de la télédétection pour proposer l'indice le plus approprié pour l'estimation de la phytomasse des terres de parcours. Dans cette étude, nous avons utilisé les données collectées sur le terrain en Avril 2018 dans la région Orientale du Maroc et huit indices de végétation (ARVI, DVI, IPVI, MSAVI, NDVI, RVI, SAVI et TSAVI) issus de trois images satellites Sentinel-2 prises en Avril 2018. Des corrélations entre la phytomasse mesurée et chacun de ces indices de végétation ont été analysées pour identifier le meilleur estimateur de la biomasse à partir des données de télédétection. Les résultats obtenus ont montré que la phytomasse des parcours varie entre 0,02 et 4,71 tonnes, avec une moyenne de 0,84 tonne par hectare dans les sites étudiés. Les indices de végétation fortement corrélés avec la phytomasse sont ARVI, IPVI, NDVI, RVI et SAVI. Les modèles polynomiaux sont mieux que les modèles linéaires. Le meilleur modèle d'estimation de la phytomasse est le RVI suivi du NDVI avec un coefficient de détermination, R^2, de 0,84 et 0,82, respectivement.*

Mots-clés. *Biomasse – Indice de végétation – Pâturage – Télédétection – Maroc Oriental.*

I – Introduction

In Morocco, rangelands occupy 75% of the country's territory (Mahyou *et al.,* 2018). The accurate estimation of forage production of Moroccan rangelands and the monitoring of its spatio-temporal variation are important for the management of pastoral resources. However, the phytomass estimation using field measurements is costly and time-consuming, especially in these large regions

where productivity per unit area is generally low and highly variable. The use of remote sensing has become the most effective approach for phytomass estimation (Barrachina *et al.,* 2015, Diouf *et al.,* 2015). Vegetation indices, calculated from remotely sensed reflectance, reflect the photosynthetic activity of the vegetation and are increasingly used to monitor rangeland productivity (Gao *et al.,* 2013). Indeed, the combination of remote sensing and field measurements makes it possible to estimate the phytomass and to provide decision-makers with information that can guide them in the management of natural resources. In this work, we aim to estimate the phytomass of rangelands in the highlands of eastern Morocco, by combining satellite data and field measurements. We will analyze the possibility of statistically linking the vegetation indices to phytomass measured during the growing season.

II – Materials and methods

The study area is located in the highlands of Eastern Morocco (34 ° 22 '12/33 ° 5' 24 N and 1 ° 42 '36' '/ 02 ° 31' 12 " W), and covers the total area of about 1 000 km². The annual average rainfall is low and irregular, about 180 mm. The average maximum air temperature is high and varies around 42.5 °C in summer, and the minimum can reach -4 °C in winter. In summer, hot and dry winds from the east and south are frequent and lead to strong sandstorms. The vegetation is composed of *Stipa tenacissima, Thymus sp, Noaea mucronata, Stipa parviflora* and *Lygeum spartum*; degraded steppes based on *Peganum harmala* or / and *Anabasis aphylla*, and steppes based on *Stipa tenacissima, Artemisia herba-alba* and / or annuals (*Schismus barbatus*) in mosaic with *Stipa parviflora, Atractilis serratuloides* and Helianthemum spp (Mahyou *et al.,* 2016).

Grazing intensity (ratio between actual animal charge and carrying capacity of rangeland) is superior to 4, indicating an overexploitation of this pasture areas.

Table 1. Description of studied vegetation indices

Index	Formula	Name	Reference
NDVI	$NDVI = \frac{(PIR - R)}{(PIR + R)}$	Normalized Difference Vegetation Index	(Rouse and Haas (1973); Tucker (1979)
RVI	$\mathrm{RVI} = \frac{R}{PIR}$	Ratio Vegetation Index	Krieger et al. (1969); Jordan (1969)
DVI	$\mathrm{DVI} = \mathrm{PIR} - \mathrm{R}$	Difference Vegetation Index	Tucker (1979)
SAVI	$\mathrm{SAVI} = \frac{(\mathrm{PIR} - \mathrm{R})}{(\mathrm{PIR} + \mathrm{R} + \mathrm{L})}$	Soil Adjusted Vegetation Index	Huete (1985)
MSAVI	$\mathrm{MSAVI} = (1 + \mathrm{L}) * \frac{(PIR - R)}{(PIR + R + L)}$	Modified Soil Adjusted Vegetation Index	Qi et al. (1994)
TSAVI	$TSAVI = \frac{\mathrm{a} * (\mathrm{PIR} - \mathrm{a} * \mathrm{R} - \mathrm{b})}{(R + a * PIR - a * b)}$	Transformed Soil Adjusted Vegetation Index	Baret et al. (1989)
ARVI	$ARVI = \frac{(PIR - RB)}{(PIR + RB)}$	Atmospherically Resistant Vegetation index	Kaufman and Tanre (1992)
IPVI	$\mathrm{IPVI} = \frac{NIR}{(PIR + R)}$	Infrared Percentage Vegetation Index	Crippen (1990)

Field data collection was carried out during April 2018. A total of 37 sampling sites were selected to measure phytomass of perennial and annual vegetation. Data were collected from three 25 m^2 quadrats within each sampling site and averaged over the quadrats to estimate the site's phytomass. The method used to measure vegetation phytomass depends on the type of plant formation: for perennial vegetation, the measurements were based on the method of the reference unit (UR) (Kirmse & Norton 1985). For herbaceous plants, the plants within a 1 m^2 quadrat was clipped at ground level and weighed. In the laboratory, all clipped phytomass were dried at 75 °C for 48 h before being weighed. Three Sentinel-2A images, with a spatial resolution of 10 m were used. These images were acquired in April. Blue, red and near-infrared spectral reflectance values were selected to calculate vegetation indices (Table 1). The vegetation indices values of the pixels of each of the 37 study sites were calculated and integrated in the statistical model described hereafter.

Linear and polynomial regressions were applied to examine the relationship between vegetation indices and the phytomass. The accuracy of the phytomass estimation models was evaluated based on two statistical indices: the coefficient of determination (R^2) and the root mean squared error (RMSE).

Table 2. Statistical models of phytomass estimation

Indices	Model	R^2	RMSE
ARVI	Linear	0.79	0.53
	Polynomial	0.81	0.50
DVI	Linear	0.31	0.94
	Polynomial	0.37	0.91
IPVI	Linear	0.79	0.52
	Polynomial	0.82	0.48
MSAVI	Linear	0.05	1.11
	Polynomial	0.53	0.79
NDVI	Linear	0.80	0.50
	Polynomial	0.82	0.49
RVI	linear	0.81	0.49
	Polynomial	0.84	0.47
SAVI	Linear	0.70	0.63
	Polynomial	0.80	0.51
TSAVI	Linear	0.69	0.63
	Polynomial	0.73	0.60

III – Results and discussion

The average phytomass of the studied sites was 0.84 T / ha, with a minimum of 0.02 T / ha and a maximum of 4.71 T / ha with a very significant variation. In fact, Among the 37 sampled sites, 22 were dominated by species indicator of degradation. The other sites are sites with weak degradation or in good condition represented by *Artemisia herba alba, Stipa parviflora* or *Stipa tenacissima*. The linear and polynomial regression models of phytomass as a function of vegetation indices were compared. The coefficient of determination (R^2) and the root mean squared error (RMSE) are presented for each model in Table 2. The result presented in this table showed that the polynomial model is globally more accurate than the simple linear regression, for all vegetation indices due to the saturation of most of the vegetation index with high phytomass production. For all studied sites, the RVI is the best polynomial model for estimating rangeland phytomass compared to other indices (R^2 = 0.84). However, it did not differ significantly from the NDVI, IPVI, ARVI or SAVI models. Indeed, the four indices were significantly correlated with phytomass in the case of the polynomial model with R^2 equal to 0.82; 0.82; 0.81 and 0.80 respectively for NDVI, IPVI, ARVI and SAVI. It should be noted

that the SAVI index did not bring any improvement over the NDVI for linear and polynomial models. The RMSE results for the different vegetation indices and the two regression models for phytomass differ from one index to another. However, the different regression models remain globally inaccurate with RMSE that vary between 0.48 and 1.1. This confirms the inaccuracy noted by Mahyou *et al*. (2018) on these empirical relationships. This is due to the fact that the state of rangeland degradation affects the relationships between these remotely sensed indices and rangeland phytomasse. RVI, in particular, showed a much better performance with RMSE value of 0.47. NDVI and ARVI indices appeared also as the best predictors of phytomass in our study area, compared to the other studied vegetation indices. They actually improved the accuracy of the phytomass estimate. However, and as shown in many studies, accurate estimation of phytomass using remote sensing data remains problematic in arid and semi-arid rangelands due to low vegetation cover and mixing of green and dead leaves of *Stipa tenacissima* (Mahyou *et al.,* 2018).

IV – Conclusions

In this study, RVI, IPVI, NDVI and ARVI indices appeared to be the best predictors of phytomass in our study area. The polynomial model of the RVI index could explain 84% of the variation of the phytomass. However, accurate estimation of phytomass using remote sensing data remains problematic in arid and semi-arid rangelands due to low vegetation cover and mixing of green and dead leaves. The indices used for the estimation of phytomass in arid and semi-arid rangelands are strongly influenced by the state of degradation of rangelands and dry and / or senescent leaves, especially in case of the alfa steppes. Therefore, the spectral signals of soil and alfa steppes and their variations must be taken into account when estimating phytomass using remote sensing data in arid and semi-arid rangelands.

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Ameliorating soil acidity improves the resilience of pasture production under extended drought

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Abstract. In an experiment beginning in 1999 and ending in 2008 conducted on soil with low pH and high levels of Al^{3+}, high levels of applied phosphorus (P, 250 kg superphosphate ha^{-1} yr^{-1}) in a treatment with no lime and a low sheep stocking rate led to high subterranean clover production for the first four years (1999 to 2002). However, clover productivity in this treatment subsequently declined to low levels and did not recover, during increasingly dry seasons of the drought that afflicted south-eastern Australia in the first decade of this Century. Conversely where high P levels were combined with lime, clover content and sward total productivity was higher and remained more stable over the longer term (up to experiment termination in 2008) under the same seasonal conditions. This was associated with lower soil Al^{3+} levels and higher pH_{Ca} after liming. At the low P application rates (125 kg superphosphate ha^{-1} every 2-3 years) subterranean clover productivity was constrained although the addition of lime had helped to improve total sward production by the end of the trial.

Keywords. Subterranean clover – Grazing pressure – Legume nutrition – Soil amelioration – Acid soils.

Une meilleure acidité du sol augmente la résilience de production des pâturages soumis à une sécheresse prolongée

Résumé. *Une expérimentation débutée en 1999 et terminée en 2008 a été conduite sur des sols à pH bas avec des teneurs élevées en Al^{3+}. De fortes concentrations en phosphore ont été appliquées (P, 250 kg de superphosphate $ha^{-1}.an^{-1}$) dans un traitement sans chaux et avec un faible taux de chargement en moutons. Ainsi une forte production de trèfle souterrain a été constatée pendant les quatre premières années (1999 à 2002). Cependant, la productivité du trèfle dans ce traitement a par la suite diminué à de faibles niveaux et ne s'est pas rétablie au cours des saisons qui étaient de plus en plus sèches, notamment avec la sécheresse qui a frappé le sud-est de l'Australie durant la première décennie de ce siècle. A l'inverse, lorsque des teneurs élevées en P étaient combinées à de la chaux, la quantité de trèfle et la productivité totale des pâturages étaient plus élevées et restaient plus stables à long terme (jusqu'à la fin des expériences en 2008) dans ces mêmes conditions saisonnières. Ceci a été associé à des niveaux plus faibles en Al^{3+} dans le sol et à un pH_{Ca} plus élevé après le chaulage. A de faibles doses d'application de P (125 kg de superphosphate ha^{-1} tous les 2-3 ans), la productivité du trèfle souterrain a été limitée, bien que l'ajout de chaux ait contribué à améliorer la production totale des pâturages à la fin de l'essai.*

Mots-clés. *Trèfle souterrain – Pression pastorale – Nutrition des légumineuses – Amélioration des sols – Sols acides.*

I – Introduction

Animal production from grazed permanent pastures is a reasonably sustainable form of agriculture on many fragile, non-arable soils. Legume productivity is crucial to most of these pastures as nitrogen (N) fixation is their primary source of N as well as providing high quality forage. Sufficient phosphorus

(P) is pivotal to maintaining legume productivity although issues of P use efficiency and methods of determining appropriate P levels remain. Moreover, the build-up of organic matter in these pastures can acidify soils, as can the removal of alkalinity with agricultural production. Soil acidity constrains pasture productivity limiting production from grazing animals. Throughout Australia it is estimated that there are 50 M ha with a soil pH_{Ca} <5.5 and associated increase in soil aluminium (Al^{3+}). Many of these areas produce meat and wool, but many Australian farmers are uncertain of the benefits of liming. Research has concentrated on the effects of lime incorporated into the 0–10 cm soil profile, although incorporation is only possible where land is arable. On the New South Wales (NSW) Southern Tablelands, large areas of non-arable soils are acidic to depth and the only option to ameliorate acidity is to surface apply lime. Therefore, an experiment was undertaken to study the effects on pasture production of different rates of lime, P and stocking rate over a time period long enough to ensure that the effects of lime would be acting to ameliorate the acid soil.

II – Materials and methods

A replicated experiment continuously stocked by sheep was conducted near Sutton, NSW, Australia (35.12° S, 149.27° E) between January 1999 and October 2008. The soils, predominately Chromosols with Leptic Rudosols in higher areas, were mainly shallow (<0.20 to >1.5 m) and stony with texture contrast having brown loam topsoils overlying reddish to reddish brown light clays and clay loams. The climate of the area is warm temperate, with average annual rainfall of 660 mm. In autumn 1998, prior to lime application, Sprayseed 250® (Paraquat, Diquat) was applied to remove annual grasses and broadleaved weeds, whilst retaining the established native perennial grasses. Sowing occurred in May 1998 using a direct drill seeder at a row spacing of 30 cm so as to minimise disturbance of the established native perennial grasses, whilst ensuring a reasonable density of introduced pasture species. The sown mix comprised *Trifolium subterraneum* (subterranean clover) cvv. Goulburn and Seaton Park LF, *Dactylis glomerata* (cocksfoot) cv. Kara, *Phalaris aquatica* (phalaris) cvv. Australian and Holdfast and *Lolium perenne* (perennial ryegrass) cv. Roper at 5.4, 2.6, 1.75, 1.75, 1.75 and 1.75 kg/ha respectively. All subterranean clover seed was inoculated and lime pelleted, with an additional application of molybdenum trioxide at approximately 100 g/ha applied to the seed. The soil was strongly acidic to depth with a pH_{Ca} ranging from 4.1 at the surface to 4.7 at 55 cm. In the 0-10 and 10-20 cm profiles Al^{3+} saturation was very high ranging from 30 to 48% of the effective cation exchange complex (ECEC), suggesting that Al^{3+} toxicity may constrain plant growth. ECEC levels were low (4.6 cmol+/kg) as were extractable P (9.7 mg/kg, and total carbon (3%).

There were three treatment factors, P, lime and stocking rate, replicated twice. All treatments received the P as superphosphate (0-9-0-11, N, P, K, S), either at a typical local application rate, P1, 125 kg/ha every 2 to 3 years, or at a high rate, P2 (250 kg/ha/yr) which reached and surpassed the critical P level (25 mg P/kg soil) across these treatments from 2002 (unpublished data). Three rates of lime were applied at experiment commencement: nil (L0); sufficient lime to increase pH_{Ca} in the 0-10 cm profile to 5.0 (L1); lime to increase pH_{Ca} in the 0–10 cm profile to 5.5 (L2). All lime applied was F70 superfine (70% < 75 µm, neutralising value = 97 %).

The experiment was continuously stocked with wethers at two rates, with the lower stocking rate (SR1) being 67% of the higher rate (SR2). The low P treatment was only stocked at SR1 whereas the high P treatment was stocked at both SR1 and SR2. Thus the treatments were combinations of two rates of P, three rates of lime and two stocking rates as follows: P1L0SR1, P1L1SR1, P2L0SR1, P2L0SR2, P2L1SR1, P2L1SR2, P2L2SR1 and P2L2SR2. A treatment P1L2SR1 was not included, it being considered unlikely to be used in practise. It was necessary to modify stocking rates due to seasonal conditions and their effects on pasture growth rates. There were extremely dry periods, when pasture growth rates were so low that plots had to be destocked for short periods. Plot sizes for SR1 and SR2 were 1 and 0.67 ha respectively.

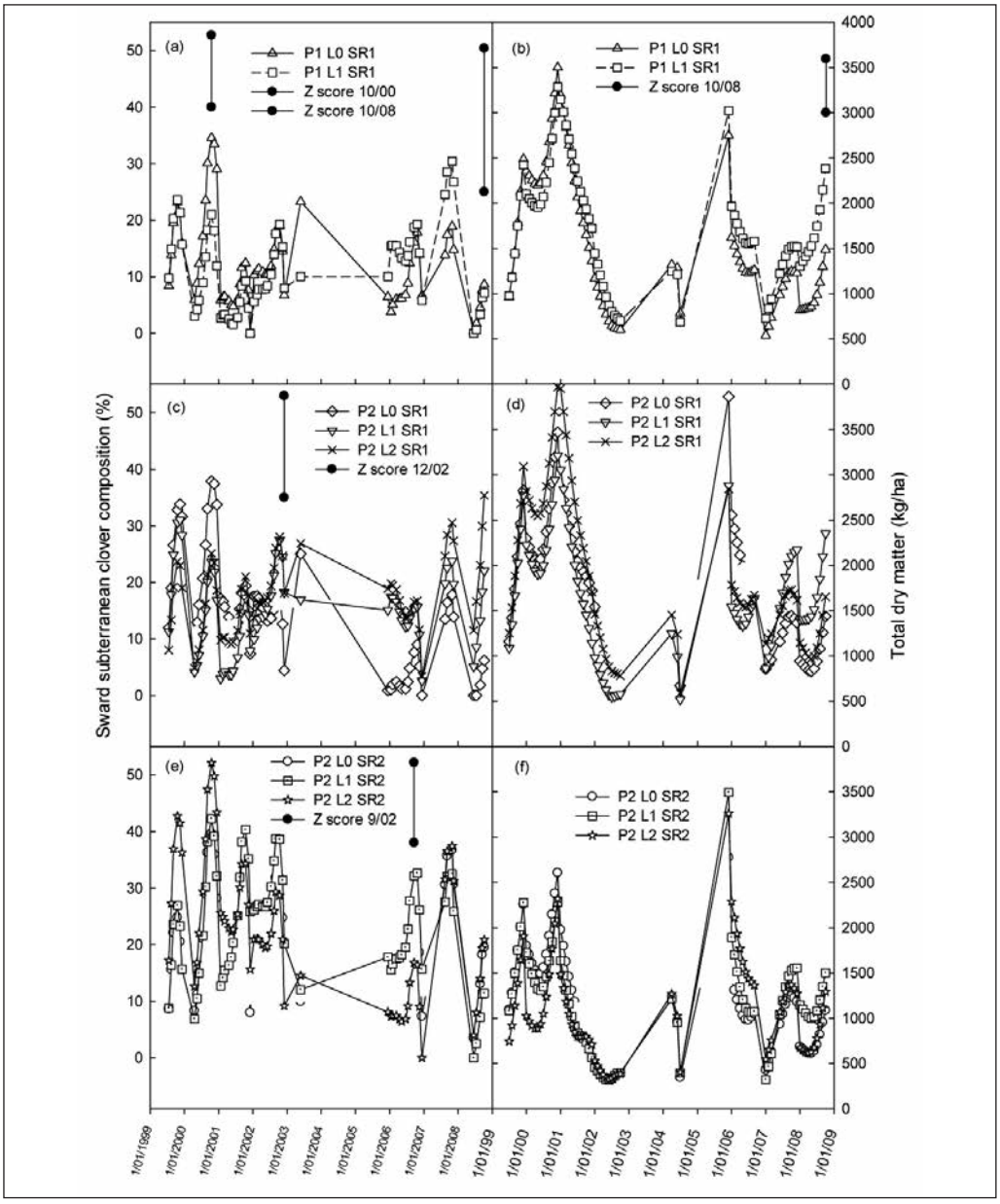

Fig. 1. The time course between 1999 and 2008 of sward subterranean clover content (%, Figs 1a, 1c, 1e) and total sward dry matter production (Figs 1b, 1d, 1f) as affected by differing levels of surface applied lime (L0, L1, L2), superphosphate (P1, P2) and two stocking rates (SR1, SR2), in the treatments P1L0SR1 (△), P1L1SR1 (□), P2L0SR2 (○), P2L0SR1 (◊), P2L1SR2 (⊡), P2L1SR1 (∇), P2L2SR2 (⋆) and P2L2SR1 (×) at Sutton, NSW, Australia. Vertical bars represent significant differences at specific measurement times between all the eight treatments for the specific parameter of the result presented in the text. Bars are only placed in one of the three graphs to minimise congestion and positioned in the frame of the major treatment comparison but apply equally to the other two graphs.

Herbage mass and botanical composition (as a percentage of herbage mass) were measured in each plot every six weeks between March 1999 and October 2008, using BOTANAL procedures except from January 2003 to November 2005 when measurements were more sporadic due to drought and funding constraints. In each plot, the pasture measurements were taken in 30 quadrats at 1-m intervals along two permanent transects chosen to sample the environmental variation. Sheep camping sites were avoided. Herbage mass was estimated directly as kg DM/ha. Statistical analyses using splines for continuous data (1999-2002, 2005-2008) and a linear mixed model for discrete data (2003, 2004) were fitted using ASReml 3.0 (Gilmour *et al.*, 2009; Norton *et al.*, 2018).

III – Results and discussion

Rainfall close to average was experienced only during the first three years of the trial from 1999 to 2001 and in 2005. From 2002, the area entered a period of below-average rainfall with altered seasonal patterns during a climatic event which has become known in Australia as the Millennium Drought. As a result substantial year to year variation was exhibited both in total pasture dry matter production and in the subterranean clover composition of the pasture (Fig. 1) with production and composition peaks associated with the high rainfall years occurring in 2000/2001 and 2005, while major declines especially in production occurred in the very dry years of 2002 and 2006.

Under the different P treatments it became clear by 2000/2001 that subterranean clover sward composition was constrained under the low P treatment (P1, Fig. 1a) as composition was higher under high P (P2, Figs 1c, 1e). Under P1 sward subterranean clover composition rarely exceeded 30% and by trial termination none of the P1 treatments had more than 9% subterranean clover. Conversely under the P2 treatments, swards with more than 30% subterranean clover were relatively common particularly under the higher stocking rate (Fig. 1e). Until June 2002 the high P, nil lime, low stocking rate treatment (P2L0SR1) was within the top producing treatment group on 23 out of the 33 occasions from the beginning of the trial up to this time. However, from that time till trial termination the subterranean clover composition of this treatment collapsed so that from August 2003, except for one occasion, P2L0SR1 was in the treatment group with the least legume. Possible reasons for this decline include an inability of the subterranean clover to access water deeper in the soil profile due to toxic levels of aluminium in the subsoil, and the possibility that taller growing and more acid soil tolerant companion species may have outcompeted the clover for water and nutrients particularly in spring when clover seedset occurs. In this context it is noteworthy that P2L0SR2, differing from P2L0SR1 only in stocking rate, had a substantially higher subterranean clover composition at trial termination (ca. 20%) and was not different from either of its comparator lime treatments, P2L1SR2 and P2L2SR2. The maintenance of a higher stocking rate may have ensured adequate seedset and thus composition, by limiting companion species competition in these three treatments (Fig.1e). However, the excellent subterranean clover sward content present in October 2008 in P2L1SR1 and P2L2SR1 (Fig. 1c) suggests that a lighter stocking rate together with a reduction of high Al levels in the subsoil, brought about by the liming, was more important for improving subterranean clover content under drought than reducing inter-species competition (Norton, *et al.*, 2018).

The role that lime application played in increasing total sward production must also be noted, particularly in P1L1SR1 and P2L1SR1. These production increases happened toward the end of the trial so that although the ongoing drought was still severe in 2008, the reduction in Al at depth which had occurred in these soils due to the lime treatments, allowed significantly greater sward production on these soils, presumably because plant roots were able to exploit a greater volume of soil for water.

IV – Conclusions

High levels of P led initially to high subterranean clover production for the first four years (1999 to 2002) in a treatment with no lime and a low sheep stocking rate. This productivity subsequently fell to low levels and did not recover on those soils which also had low pH and high levels of Al^{3+}. Superimposed over these results was an extended drought period becoming more intense as the trial progressed. Where high P levels were combined with lime, clover content and sward total productivity was higher and remained more stable over the longer term (up to experiment termination in 2008) under the same dry seasonal conditions. This was associated with lower soil Al^{3+} levels and higher pH_{Ca} after liming. At low P rates subterranean clover productivity was constrained although the addition of lime helped to improve total sward production by the end of the trial.

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Weaning weight and compensatory growth in lambs from Ouled *Djellal* breed (Algeria)

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Abstract. As a leading supplier of red meat in Algeria, sheep are the only animals of high economic value to be able take advantage of pasture areas, especially in the steppe. Despite the existence of other breeds, sheep farming is dominated by the *Ouled Djellal* breed, which is well adapted to the conditions of the environment. Nevertheless, the low productivity contributes to an insufficient production of red meat and little scientific work is devoted to it. In a previous work, we showed that, in this breed, birth weight influences preweaning growth. In the present study, we propose to measure the influence of weight at weaning on growth and check the ability of this breed to catch up with growth (compensating growth). For this purpose, thirty *Ouled Djellal* lambs, born in autumn and weaned at four months of age, were divided into two lots of fifteen according to their weight. The average daily gain of the "skinny" lot was 158 ± 14 g and 139 ± 8 g for the two periods ranging from 120 to 150 and 120 to 210 days of age respectively. That of the "Normal" lot was 130 ± 13 g and 98 ± 9 g for the two periods ranging from 120 to 150 and 120 to 210 days of age respectively. The growth rate is statistically different (p = 0.002) between the two groups for the period 120-210 days of age. All the lambs were fattened for three months under almost similar conditions, especially feeding. At the end of the post-weaning growth period at the seventh month of age, the lambs weighed 29.1 ± 5.1 kg for the light group and 36.4 ± 4.1kg for the heavy group (p = 0.109). This would confirm the ability of this breed to adapt to rearing conditions by, for example, an appreciable compensatory growth. This will constitute an additional parameter of adaptation of this breed to the conditions, often unfavorable for breeding. Further studies are needed to confirm and quantify this compensatory growth.

Keywords. Lambs – *Ouled Djellal* – Post weaning – Compensatory growth – Fattening.

Poids au sevrage et croissance compensatrice chez les agneaux de la race Ouled Djellal (Algérie)

Résumé. *Premier fournisseur en Algérie de viande rouge, le mouton est le seul animal de haute valeur économique à pouvoir tirer profit des espaces de pâturage notamment la steppe. Malgré l'existence d'autres races, l'élevage ovin est dominé par la race Ouled Djellal bien adaptée aux conditions du milieu. Néanmoins, la faible productivité concourt à une insuffisance de la production de viandes rouges et peu de travaux scientifiques lui sont consacrés. Dans un précèdent travail, nous avons montré, chez cette race, que le poids à la naissance influence la croissance pré-sevrage. Dans la présente étude, nous nous proposons, cette fois ci, de mesurer l'influence du poids au sevrage sur la croissance et vérifier l'aptitude de cette race à rattraper sa croissance (croissance compensatrice). Pour ce faire, trente agneaux de race Ouled Djellal, nés en automne et sevrés à quatre mois d'âge, ont été répartis en deux lots de quinze selon le poids. Le lot 1 « Chétif » est constitué d'agneaux relativement Chétifs, alors que le lot 2 « Normal » est constitué des agneaux plus lourds. Le gain moyen quotidien du lot « Chétif » a été de 158 ± 14 g et 139 ± 8 g pour les deux périodes allant de 120 à 150 et de 120 à 210 jours d'âge respectivement. Celui du lot « Normal» a été de 130 ± 13 g et 98 ± 9 g pour les deux périodes allant de 120 à 150 et de 120 à 210 jours d'âge respectivement. La croissance est statistiquement différente (p=0,002) dans les deux groupes pour la période de 120 à 210 jours d'âge. La totalité des agneaux ont été engraissés durant trois mois dans des conditions d'élevage quasiment similaires, l'alimentation notamment. A la fin de la période de croissance post-sevrage, soit l'âge de sept mois, les agneaux des deux lots ont enregistré des poids statistiquement identiques (p = 0.109) soit 29,1 ± 5,1 kg le lot dit « Chétif » et 36,4 ± 4,1kg pour le lot «Normal». Ceci confirmerait l'aptitude de cette race à s'adapter aux conditions d'éle-*

vage par, notamment, une croissance compensatrice appréciable. Ce qui constituera un paramètre supplémentaire d'adaptation de cette race aux conditions, souvent défavorables d'élevage. Des études complémentaires sont nécessaires pour confirmer et quantifier cette croissance compensatrice.

Mots-clés. *Agneaux – Ouled Djellal – Post sevrage – Croissance compensatrice – Engraissement.*

I – Introduction

In Algeria, sheep farming is very old (Jores d'Arce, 1947; Chellig, 1992). Sheep are distributed throughout the country, with the *Ouled Djellal* breed dominating in the steppe and semi-arid high cereal plains (Khelifi, 1999), as well as in the Sahara, exploiting the resources of oases and desert routes (Kerboua *et al*., 2003). The Ouled Djellal breed thus occupies a preponderant place at the national and even the Maghrebine scales because of these proven qualities; nevertheless, many of its characteristics remain unknown.

Currently, sheep are the largest supplier of red meat in Algeria, and therefore fattening of lambs remains one the relevant animal speculations. Thus, further studies on the exploited breeds are needed in order to improve zootechnical performance and specify some levers of success. The possible exploitation of compensatory growth in this breed is one of these levers, since these animals are subject to more or less severe nutritional restrictions during their breeding period. Feeding remains the most effective way to improve zootechnical performance. Unfortunately, sheep farming in the arid and semi-arid regions of Algeria is facing large fluctuations in pastoral supply. The feeding system of ruminants in these areas is characterized by insufficient forage supply both qualitatively and quantitatively. Even worse, this situation is likely to increase with climate change. In such a difficult environment, imposing an extensive breeding system, it is very difficult to predict the quantity and quality of the dry matter intake from rangelands.

The extensive nature of a livestock system is often linked to the land factor and associated with low production per hectare compared to intensive situations. The economic viability of extensive systems is based on a substantial reduction in consumption by feeding adapted to environmental constraints thus favoring grazing (Beranger 1992). Despite the extensive nature of this livestock system, the national sheep herd continues to grow to around 28 million head in 2017 (FAOSTAT, 2018).

Knowing that the feeding season affects the growth of lambs (Dimsoski *et al*., 1994), domestic ruminants are fed by spontaneous annual vegetation of natural pastures, fallows and agricultural residues, mainly Straw. Different types of dry hay from natural or cultivated grasslands are marketed. It is obvious that any program for improving the performance of a population or an animal breed necessarily requires a phenotypic characterization.

Given its dominance in Algerian sheep flocks, the *Ouled Djellal* breed deserves special attention. Thus, this study was undertaken to provide additional information for a better knowledge of the *Ouled Djellal* breed and the Algerian sheep farm. Its purpose is therefore to verify the impact of weaning weight on the growth of *Ouled Djellal* lambs breed in real production conditions, and therefore to know the ability of the breed to catch up with its growth.

II – Materials and methods

This research was carried out in a pilot farm, in the semi-arid region of Bordj Bou Arreridj (BBA) in eastern Algeria. The region is famous for the production of cereals and sheep farming.

The lambs graze about 8 hours a day, evenly distributed between morning and afternoon, with a modest complement of barley grain and straw cereals in sheepfold. They drink twice a day at the time of their release to the pasture.

Thirty lambs from *Ouled Djellal* breed, born in autumn, were chosen for experimentation. The lambs were raised in the flock. The weight change of the lambs was monitored for three months. Two groups of lambs are made up: the first group of lambs known as "Skinny" with weaning weight less than 25 kg (<25 kg) and the second group called "Normal" with live weight greater than or equal to 25 kg (≥ 25 kg). Lambs were weighed before access to feed in the morning at 120, 150, 180, and 210 days of age using a 100 kg scale (accuracy of 0.5 kg). Average daily gain (ADG) was determined for the following periods: 120-150, 150-180, and 180-210 days of age.

Descriptive statistics and comparison of average daily gain results of lambs between 120-150 and 120-210 days of age were analyzed using the Student t-test by XLSTAT software (version 2016) for ADG analysis of both groups. All means were calculated with their standard errors (mean ± SE).The risk of error is considered at P <0.05.

III – Results and discussion

1. Weight at weaning and at seven months old

The average live weight of Ouled Djellal lambs at seven months of age was 32.74 ± 1.07 kg, similar to the weights reported by Boussena (2013) for the same breed, and by Mahouachi *et al. (*2000) for the Thin tail breed lambs of the West, fed comparable diet. However, they were lower than those observed with Sardi breed lambs (Jorfi *et al.,* 2013) and much lower than those obtained by Prache *et al.* (1986) with Ile-de-France breed lambs, grass-fed supplemented with concentrates *ad libitum*. Again, they were superior to those displayed by D'Man breed lambs in traditional breeding (Boujenane and Kerfel, 1992; Boujenane, 1999). Overall, for the entire trial period (Day 120 – Day 210), the lambs from "Skinny" and "Normal" groups gained 12.47 ± 0.37 and 8.79 ± 0.56 kg liveweight respectively (Table 1).

Table 1. Live weight (kg) evolution of *Ouled Djellal* breed lambs according typical ages

Typical age	«Skinny» Lambs*	«Normal» Lambs*	All lambs*
120 – 150 Day	17.10±1.17	27.10±0.43	22.10±1.11
150 – 180 Day	21.86±1.32	31.02±0.72	26.44±1.13
180 – 210 Day	25.50±1.25	34.54±1.18	30.02±1.27
120 – 210 Day	29.57±1.54	35.90±0.99	32.74±1.07

*: Mean ± standard error.

Naturally, all lambs end up with a higher weight. However, difference in weight in favor of lambs born "Normal" is to report (35.90 ± 0.99 *Versus* 29.57 ± 1.54 kg).

2. Average daily gain and effect of weaning weight on lambs absolute growth

The weight gain evolution according to the typical ages is variable for the thirty lambs. Nevertheless, a difference is observed in favor of "Skinny" lambs. In fact, the "Skinny" lambs recorded a higher ADG (139 g/day) than "Normal" lambs (98 g / day) with an average difference of 41 g/day (Table 2).

This variation can be explained beforehand by the fact that lambs weaned with light weights tend to ingest more dry matter, obviously accompanied by a better digestion yield. In any case, it is shown that compensating cattle had a heavier digestive tract (Wright and Russel, 1991). It should be noted that in such a difficult environment, imposing both a similar feeding system, it is very difficult to predict the quantities and the quality of dry matter ingested at the levels of the rangelands. This constraint can be explained by many factors related to both the surfaces, the animals, the pe-

riod and the management of grazing (Roguet *et al.,* 1998). Nevertheless, these growth rates are much lower than those reported by Kerfal *et al.* (2005) for D'Man lambs breed in Morocco; averaging 189 g/day from 90 to 135 days old. They are also inferior those obtained by Aboud et *al*. (2016) with Ouled Djellal breed.

Growths between 120 and 210 days are an indication of the growth potential: the lambs are weaned at 120 days of age and the mother milk production factor is no longer involved. Obviously, our initial objective is not the determination of the maximum potentials, but that of the potentials in real breeding environment, comparable to that of a traditional breeding in a difficult environment; semi-arid in particular. Overall, the growth of lambs can seem modest compared to the values obtained with improved breeds, this is due to the unavailability of concentrates and the nature of the breeding practices.

Regardless of the performance control period (J120-J150, J150-J180 or J180-J210), growth levels are characterized by large individual variations in both groups (P <0.001) and are more pronounced among "Skinny" lambs. Our results indicate that low weaning weight has a highly significant effect (p <0.001) on lambs weight (Table 2). In other words, we will note an important manifestation of compensatory growth in lightest animals at weaning.

Table 2. Average daily gain (g/d) evolution of *Ouled Djellal* breed lambs

Periods	«Skinny» Lambs*	«Normal» Lambs*	P Value
120-150 Day	158±14	130±13	0.172
150-180 Day	121±14	117±25	0.900
180-210 Day	136±17	45±25	0.007
120-210 Day	139±08	98±09	0.002

*: Mean ± standard error.

Our present result is similar to that reported by Prache *et al.* (1986). The latter authors, state that weaning followed by finishing in sheepfold results in an increase growth speed which is more important when the animals has had a low growth rate under the mother. By stating that average increase growth after weaning was 134 g/day and 65 g/day respectively for groups of lambs with slow and fast growth rates under the mother. In addition, Allden (1968) showed that sheep undergoing dietary restrictions during the first six months of life were catching up in much more time than those restricted during their second half-year of growth. The first advantage of compensatory growth is the animals adaptation to difficult conditions, thus producing lean carcasses. In this sense, it is sometimes reported in cattle that animals with compensatory growth were leaner than continuously growing animals (Mc Manus *et al*., 1972). In this same context, it is found that moderately trained animals deposit more subcutaneous fat (Wright and Russel, 1991).

IV – Conclusion

It appears that the *Ouled Djellal* lambs are adapting well to difficult breeding conditions, particularly under feeding. Therefore, they are able to compensate their delayed growth caused during the period before weaning. However, a thorough study with larger number of lambs is needed to confirm these results.

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The degradation of rangelands in the Middle Atlas during the last decades

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Abstract. The study was carried out in the territorial Community of Timahdit, Morocco. This study aims to assess changes in landscape pattern and vegetation standing crop during the last four decades. Changes in land cover were assessed by using remote sensing from Landsat-5 Thematic Mapper (TM) for 1984, 2007 and 2016. Images were analyzed by supervised classification for identification of land cover types. Vegetation surveys were performed in 1979 and 2017 to assess changes in vegetation standing crop. The results showed changes in percent of land occupation. Forest area declined by 77.50%. Grasslands area decreased slightly (4%). Shrub cover remained unchanged and the amount of bare ground varied among years. Total standing crop of biomass did not change between 1979 and 2016. Changes occurred in standing crop of plant functional group and individual species with increaser weed species replacing palatable native species.

Keywords. Grassland – Biodiversity – Livestock impacts – Rangeland degradation – Middle Atlas.

La dégradation des terres de parcours dans le Moyen Atlas au cours des dernières décennies

Résumé. *L'étude a été réalisée dans la Communauté territoriale de Timahdit, au Maroc. Cette étude vise à évaluer les changements dans la configuration du paysage et de la végétation sur pied au cours des quatre dernières décennies. Les changements dans la couverture du sol ont été évalués en utilisant la télédétection de Landsat-5 Thematic Mapper (TM) pour 1984, 2007 et 2016. Les images ont été analysées par classification supervisée pour l'identification des types de couverture du sol. Des relevés de végétation ont été effectués en 1979 et 2017 pour évaluer les changements dans la végétation sur pied. Les résultats ont montré des changements dans le pourcentage d'occupation des terres. La superficie des forêts a diminué de 77,50%. La superficie des pâturages a légèrement diminué (4%). La superficie arbustive et e maquis est resté inchangé et la quantité de sol nu a varié selon les années. La biomasse totale sur pied n'a pas changé entre 1979 et 2016. Des changements ont été observés dans la biomasse des groupes fonctionnels de plantes et des espèces individuelles, les espèces de mauvaises herbes envahissantes remplaçant les espèces indigènes palatables.*

Mots-clés. *Pâturages – Biodiversité – Impacts du bétail – Dégradation des parcours – Moyen Atlas.*

I – Introduction

For many pastoral societies such as those in the Middle Atlas of Morocco, ecological integrity of the pastoral systems that sustained natural resources for long time depended of on mobility of people and herds. As most of the Middle Atlas producers, those of the Ait Arfa du Guigou tribe used to be transhumant between winter grazing (lowlands) areas and summer ones (higher lands). Conversion to cultivation of the lowlands (winter grazing areas) reduced the grazing areas and caused a break down in the double transhumance. Consequently, herders reduced their mobility and started settling in the summer high grazing lands. This study aims to assess changes in landscape pattern and vegetation standing crop during the last decades.

II – Methods

The study was carried out in the territorial Community of Timahdit (TCT), home of the Ait Arfa de Guigou tribe. The climate is semiarid. Winters are cold with mean minimum temperature of -2.5°C and mean maximum temperature of 9.8 °C for the month of January. The hottest month is August with mean maximum temperature of 31°C and mean minimum of 13.6°. Annual precipitation ranged from 800 mm in the North of (TCT) at 2000 m elevation to 300 m South of the Timahdit village.

Changes in land cover were assessed by using remote sensing from Landsat-5 Thematic Mapper (TM) for 1984, 2007 and 2016 were analyzed by supervised classification for identification of land cover types. Vegetation surveys were performed in 1979 and 2017 to assess changes in vegetation standing crop. Twenty transects that ran east to west and spaced 4.5 meters apart were used to determine Standing crop of biomass. Standing crop of biomass was sampled by clipping vegetation within a 0.33 m^2 circular quadrat. Clipped vegetation was oven dried at temperature of 65°C for 48 hours to estimate production expressed as dry matter expressed as g/m^2.

III – Results and discussion

Our results indicated a change in percent of land occupation (Table 1). Forest area declined. Matorrals of *Artemisa spp* and Xerophytic species (*Buplorum spinosum* and *Erinacia anthyllis*) remained unchanged. The matorral of *Genista pseudopilosa* increased. The area of the grasslands decreased slightly. Finally, the amount of bare ground varied among years, but remained important leading to a great amount of fragmentation. Croplands area is decreasing in percent of total. These changes in land cover indicated trend toward land degradation (Kouba *et al.,* 2018).

Table 1. Percentage of land cover of the Timahdit during 1984, 2007 and 2016

	1984	2007	2016
Croplands	13.16	12.92	9.33
Dense forests	15.63	13.35	3.69
Xerophytic shrubs	20.51	22.09	21.67
Genista spp	6.92	4.89	31.55
Artemisia spp	7.26	7.79	7.67
Grasslands	20.34	21.34	17.01
Bare ground	11.09	15.25	8.95
Wetland	2.54	1.17	0.13
Unknown	2.55	1.19	0.00

The total production of biomass did not change between 1979 and 2016. It averaged 698.2 kg DM/ha and 648.82 Kg DM/ha for 1979 and 2016, respectively. However, changes occurred in composition of standing crop. Production of grasses remained unchanged between 1979 and 2016 ($P>0.05$). Grass like, represented by *Carex divisa*, increased significantly years since it increased from less than 4% in 1979 to 21.52 ($P<0.01$). Production of low shrubs (*Thymus algeriansis, Helianthemum croceum* and *Alyssum montanum*) decreased from10.89 g DM/m^2 in 1979 to 3.15 g DM/m^2 in 2016 as response to continuous over grazing; i. e., stocking rate average in the grazing area around 4.5 ewe/ha (Fig. 1).

The low shrub contribution to standing crop of biomass decreased from 44.87% to 14.73% Annual forb species increased with years.

Comparison of standing crops of individual species indicated that there are some species that decreased in 2016 as compared to 1979. These species are the key species for the Middle Atlas grasslands. Among them, we find the most palatable grasses such as *Dactylis glomerata* ($P<0.01$),

Festuca ovina (P<0.05), and *Poa bulbosa* (P<0.01) and the subshrub *Thymus algeriencis* (P<0.01). These species are the ones that suffered from overgrazing during the last 37 years. The species that seemed to replace the one that are decreasing are *Stipa lagascae*, *Carex divisa*, *Filago germanica*, *Scléranthus annuus*, *Tunica ilirica*. These species have low pastoral value for sheep. There are some species that remained unchanged when comparing the two years studied. It is the case of *Bromus tectorum*, *Dasypyrum hordeaceum*, *Koeleria spendens*, *Phleum phleoides*, *Convolvulus cantabrica*, *Dianthus caryophyllus*, *Echinaria capitata*, *Euphorbia nicacensis*, *Hierarcium pseudopilosa*, and *Ranunculus orientalis.* This last group is composed of annual species and those that are not palatable (Chryaa 1982 and El Aich *et al*., 1980).

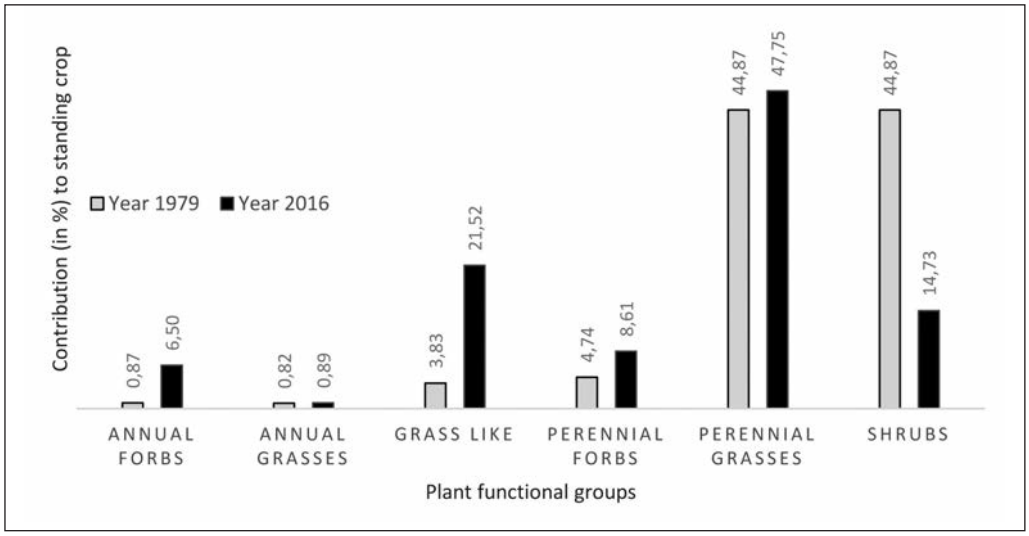

Fig. 1. Contribution (in%) to total standing crop biomass of plant functional groups (in g DM/m^2) during 1979 and 2016.

IV – Conclusions

The main conclusions of this study are: the changes in land cover, the maintenance of the standing crop of biomass and the change in the floristic composition of the pasture. The study showed the capacity of resilience of the Middle Atlas grasslands since the precipitation are not limiting factor. However, the question is whether these grasslands will continue to have the same capacity of resilience.

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Germination of *Salsoa vermiculata* seeds as affected by temperature and storage duration

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Abstract. *Salsola vermiculata* L. Syn. *Caroxylon villosum* (Delile) Akhani & Roalson (*Chenopodiaceae*) is a perennial small woody species widely distributed in arid zones of Middle East and North Africa (MENA) region. It is one of the promising pastoral species for the rehabilitation of arid rangelands in Mororcco. The objectives of this study were to determine the effects of temperature and duration of seed storage on the germination of *Caroxylon villosum* (*Salsola vermiculata* var villosa). Experiments were conducted in the laboratory of the Experimental station of Errachidia (Morocco). Seeds were germinated at six alternating temperatures (10 – 0, 5 – 15, 10–20, 15–25, 20–30 and 25 – 40 °C) with 14-8 h photoperiod and six cardinal temperatures (5, 15, 20, 25, 30 and 40 °C). Three storage durations of seeds under ambient conditions (seed of the same year of production, 2 years storage and 4 years storage) were tested. Germination percentage and germination rate were high for several regime of temperature except for higher temperatures. In addition, germination decreases significantly with the duration of seed storage.

Keywords. *Caroxylon villosum* – Rehabilitation – Temperature – Storage duration – Arid pastures.

Résumé. Salsola vermiculata L. *(Chenopodiaceae) est un ligneux bas largement répandue dans les zones arides dans le Moyen-Orient et l'Afrique du Nord (MENA). C'est l'une des espèces pastorales prometteuses pour la réhabilitation des pâturages arides du Maroc. Les objectifs de cette étude étaient de déterminer les effets de la température et la durée de stockage des graines sur la germination de* Caroxylon villosum (Salsola vermiculata *var villosa). Les essais ont été menés dans une enceinte de germination au laboratoire de la station expérimentale d'Errachidia (Maroc). Les graines ont été germées à six températures alternes (10 à 0, 5 à 15, 10 à 20, 15 à 25, 20 à 30 et 25 à 40 ° C) avec une photopériode de 14 à 8 h et six températures cardinales (5, 15, 20 25, 30 et 40 ° C). Trois durées de stockage des graines dans les conditions ambiantes ont été testées (semences de la même année de production, 2 ans de stockage et 4 ans de stockage). Le pourcentage de germination et le taux de germination étaient très élevés pour plusieurs régimes de température, sauf pour les températures plus élevées. En outre, elle a diminué très significativement avec la durée de stockage des graines.*

Mots-clés. *Caroxylon villosum – Réhabilitation – Température – Durée de stockage – Pâturages arides.*

I – Introduction

Salsola vermiculata L. (Mediterranean saltwort, shrubby Russian thistle, sisallo, rama), a perennial shrub of the family Amaranthaceae. It is a Saharo-Sindien and Mediterranean species with a large geographical repartition. It is one of the most valuable dominant browse in arid zones of North Africa, South Europe, and Southwest Asia (Creager, 1988; Neffati *et al*., 1993;). Many varieties were describe for this species like the one used in this study: *Salsola vermiculata* var. villosa (Delile) Moq. (1840) under the actual name *Caroxylon villosum* (Delile) Akhani & Roalson (according the Geneva plant database).

Salsola vermiculata L. s.l. is also one of the most promising species for rangeland rehabilitation as it contributes to revegetation of degraded rangelands thanks to their potential selfreseeding and can be established from direct seeding (Osman and Ghassali, 1997). It was considered convenient for that purpose and it has been also reported as valuable and palatable forage for goats, sheep

and camels in arid regions (Osman *et al*., 2006). Moreover, its integration in dry areas could not only reduce feed gaps but also stop desertification processes. The crude protein in *C. villosum* varied from 7.1% in winter to 16.4 % in spring while Digestability ranged from 44 % to 49 % in winter and spring, respectively (Assaeed, 2001).

Successful rangeland rehabilitation requires basic knowledge of germination requirements of the potential species to be utilized. Therefore, the objective of this study was to determine the effect of six alternating temperatures regime, six cardinal temperatures and three seed storage duration on germination characteristics of *C. villosa* seeds.

II – Materials and methods

1. Seed origin, collection and storage

Seedling of *C. villosum* (2010 harvest) were obtained at first from the regional center of Oujda in the Oriental part of Morocco, which received the seeds from the International Center for Agricultural Research in the Dry Areas (ICARDA). The original site of collection was located in northern Saudi Arabia. We started to harvest the seeds one year after its plantation in the Experimental Station of Errachidia (Centre-East of Morocco), then we harvested these seeds two years and four years later. They were stored at the temperature of laboratory conditions.

2. Germination experiments

Seeds were germinated on filter papers placed within 15 cm diameter plastic dishes. Four Petri dishes per treatment (50 seeds per dish) were placed within controlled environment chambers (incubator permitting to fix the temperature, photoperiod and intensity of light). Chambers were illuminated for 14 hours daily. Each experiment was replicated four times. Seeds were considered germinated when radicles were >1 mm long. Germinated seeds were counted daily until germination ceased (on average 30 days). Petri dishes were moistened with the same quantity of water every two to three days according to the dryness of the filter paper (its dryness differ according to temperature). Effect of temperature on germination seeds of *C. villosum* was determined by incubating them at twelve temperature regimes (Table 1).

Table 1. Treatments used in this study

Code	Cardinal temperature °C	Code	Alternate temperature °C
C1	40 ° – (<1 year)	A1	40/25 ° – (<1 year)
C2	30 ° – (<1 year)	A2	30/20 ° – (<1 year)
C3	25 ° – (<1 year)	A3	25/15 ° – (<1 year)
C4	20 ° – (<1 year)	A4	20/10 ° – (<1 year)
C5	15 ° – (<1 year)	A5	15/5 ° – (<1 year)
C6	5 ° – (<1 year)	A6	10/0 ° – (<1 year)
C5B	15 ° – 2 years	A5C	15/5 ° – 2 years
C5D	15 ° – 4years	A5D	15/5 ° – 4 years °

3. Germination indices

Germination was monitored daily. Counting number of germinating seeds began from the first day and was done till the end of the experiment (30 days). Nine germination indices were calculated to describe the process of germination: germinability (G%) or final germination percentage (FGP); mean germination time (MGT); coefficient of variation of the germination time (CVt); mean germi-

nation rate (MGR); germination rate index (GRI); coefficient of velocity of germination (CVG) (Speed of germination); mean daily germination (MDG) (number of seeds per day); germination value (GV); U: uncertainty of germination and Synchrony of germination (Z). Time, rate, homogeneity, and synchrony are aspects that can be measured, informing the dynamics of the germination process. Uncertainty measurement is an adaptation of the Shannon index and measures the degree of uncertainty associated to the distribution of the relative frequency of germination (Ranal and Santana 2006). Low values indicate more synchronized germination. According to Ranal and Santana (2006), the synchrony of germination of one seed with another assumed Z=1 when the germination of all seeds occur at the same time and Z=0 when at least two seeds can germinate, one at each time, in fact it is a degree of germination overlapping. All the germination parameters were calculated according to formulas given by Ranal and Santana (2006).

4. Data analysis

All data were submitted to one-way analysis of variance (ANOVA) and the averages of treatments were compared according to the method of Newman and Keuls to determine the significance of seed germination percentage under each treatment. SPSS program for windows Version 18.0 was used to perform these analysis. Excel 2007 software was used to transform data and to calculate different indices based on the work of Ranal *et al*. (2009).

III – Results and discussion

1. Effect of temperature

The statistical analysis of variance showed a significant effect of the alternating/ cardinal temperature regimes and storage duration of seeds on almost all parameters of germination (Table 2).

Table 2. Germination characteristics of *C. villosum* in response to different temperature combine to the storage duration

Temperatures	G (%)	MGT (day)	CVT (%)	MGR (day^{-1})	U (bit)	Z (unit less)	GRI (day)	CVG (%)	GV %day^{-2})	MDG (%)
A1	2.0^{a}	1.5^{a}	0.0^{a}	0.38^{ab}	0.00^{a}	0.00^{a}	1.0^{a}	37.5^{ab}	0.1^{a}	0.1^{a}
A2	**87.5^{d}**	3.1b^{c}	24.5^{b}	0.32^{ab}	1.37^{c}	0.49^{d}	29.5^{cd}	31.9^{ab}	70.0^{ef}	2.9^{d}
A3	**98.0^{d}**	3.8^{c}	47.9^{ef}	0.26^{ab}	2.39^{e}	0.22^{b}	31.4^{cd}	26.4^{ab}	62.5^{de}	**3.3^{d}**
A4	**96.0^{d}**	3.1^{bc}	42.6^{cdef}	0.32^{ab}	1.70^{cd}	0.38^{cd}	34.3^{de}	32.1^{ab}	**83.3^{f}**	**3.2^{d}**
A5	**98.0^{d}**	3.8^{c}	40.9^{cdef}	0.27^{ab}	1.93^{d}	0.34^{c}	29.9^{cd}	26.5^{ab}	70.2^{ef}	**3.3^{d}**
A6	**96.5^{d}**	**6.2^{d}**	**52.7^{f}**	0.16^{a}	**3.04^{f}**	0.13^{b}	19.3^{b}	16.1^{a}	35.0^{c}	**3.2^{d}**
C1	1.5^{a}	1.5^{a}	0.0^{a}	0.38^{ab}	0.00^{a}	0.00^{a}	0.8^{a}	37.5^{ab}	0.1^{a}	0.1^{a}
C2	37.5^{b}	2.4^{b}	33.6^{bcde}	**0.42^{b}**	1.03^{b}	**0.61^{e}**	16.8^{b}	**41.9^{b}**	18.2^{b}	1.3^{b}
C3	73.5^{c}	2.8^{b}	27.5^{bc}	0.36^{ab}	1.41^{c}	0.43^{cd}	28.6^{c}	36.3^{ab}	52.3^{d}	2.5^{c}
C4	**93.5^{d}**	2.8^{b}	44.8^{def}	0.36^{ab}	1.67^{cd}	0.41^{cd}	**38.2^{e}**	36.2^{ab}	**85.7^{f}**	**3.1^{d}**
C5	**98.0^{d}**	2.9^{bc}	30.6^{bcd}	0.34^{ab}	1.65^{cd}	0.33^{c}	**36.6^{e}**	34.2^{ab}	**79.7^{f}**	**3.3^{d}**
C6	**92.5^{d}**	7.0^{e}	40.7^{cdef}	0.14^{a}	**3.26^{f}**	0.12^{b}	16.1^{b}	14.3^{a}	26.6^{bc}	**3.1^{d}**

Numbers with different letters (a to d) are significantly different by Newman & Keuls test at $p < 0.05$.

For the same storage duration of seeds (fresh seeds <1year), generally alternating temperatures regimes were better than some cardinal temperatures. The test of Newman & Keuls (SNK) defined four groups of cardinals temperatures and only two groups of alternating temperatures for the germinability parameter. Highest germination percentage (98 %) was observed when seeds were ger-

minated at cardinal temperatures (C5=15°C) and alternating temperature A3 (15/25°C) and A5 (5/15°C). Lowest germination percentage always for fresh seeds was observed for higher temperature (A1= 25/40°C, C1=40°C and C2=30). Furthermore, SNK test distinguished many groups for other parameters of germination ($p<0.01$).

2. Effect of storage duration under ambient temperature

Regarding the duration of storage, it affects significantly all parameters of germination. Most important is that the germination faculty is reduced to the half after two years and almost all seeds lost their germination faculty after four years of storage (Table 3).

Table 3. Total percentage germination of the fresh harvested *C. villosum* in response to the duration of storage

Temperatures	G (%)	MGT (day)	CVT (%)	MGR (day^{-1})	U (bit)	Z	GRI (day)	CVG (%)	GV $\%day^{-2}$)	MDG (%)
A5	**98.00^{d}**	3.79^{b}	40.91^{b}	0.27^{c}	1.93^{bc}	0.34^{d}	29.89^{c}	26.50^{c}	70.19^{c}	0.31
A5B	43.50^{c}	4.05^{b}	41.36^{b}	0.25^{c}	2.29^{c}	0.23^{c}	12.29^{b}	25.16^{c}	10.98^{b}	0.74^{c}
A5D	9.00^{b}	5.49^{c}	33.90^{b}	0.19^{b}	1.69^{b}	0.11^{b}	1.75^{a}	18.86^{b}	0.39^{a}	5.75^{d}
C5	**98.00^{d}**	2.93^{b}	30.60^{b}	0.34^{d}	1.65^{b}	0.33^{d}	36.58^{d}	34.18^{d}	79.65^{c}	0.31
C5B	36.00^{c}	4.02^{b}	35.27^{b}	0.26^{c}	2.04^{bc}	0.27^{cd}	10.34^{b}	26.25^{c}	8.48^{b}	0.85^{c}

Numbers with different letters (a to d) are significantly different by Newman & Keuls test at $p < 0.05$.

The two most important results are:

First we should use fresh seeds for *C. villosum* and they should not be stored over two years at the temperature of laboratory conditions because the faculty of germination is halved. Several studies indicated that some species of Amaranthaceae including Salsola genera have shortlived seeds under natural conditions (Sankary and Barbour 1977; Creager 1988; Al-Rowaily 1999). Loss of seed viability with time could be compensated by the remarkable ability of plant to produce a huge amount of seeds.

The second most important result is the ability to use seeds several times during the year because the fresh seeds germinate very well at several alternating temperature, of course only the summer period should be avoided as the increase of temperature decreases the germinability, which is in concordance with the results obtained by Guma *et al*. (2010) and Neffati *et al*. (1993). These last authors stated that optimum germination is between 5 and 25 °C. Also Sankary and Babour (1972) reported that the optimum temperature of germination of this species is between 12 and 18 °C.

IV – Conclusion

Caroxylon villosum showed excellent germinability and it is promising pastoral species for the rehabilitation by reseeding of arid lands in the Centre-East of Morocco under the condition of using fresh seeds. Nevertheless, more research in the field on its establishment and behavior towards browsing should be done.

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Local knowledge on Moroccan Siroua sheep management assists its resilience to climate change

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Abstract. Indigenous livestock genetic resources play a significant role in promoting biodiversity and improving ecosystem resilience to climate change in their area. In Center-eastern Morocco, Siroua sheep is a good example of adaptation to harsh environments in high altitudes (1800 m to more than 3000 m) where rainfall is very low and irregular (115 to 260 mm/year) and temperatures vary from –5 to +20 °C in winter and from +30 to +45 °C during summer. The aim of this study was to explore how herders and shepherds manage the Siroua sheep to mitigate climate change impacts. Based on the results of a prospective study and a field survey, sheep feeding is based mainly on rough grazing lands through transhumance between high mountain pastures in summer and lowlands in winter. Thus, the local knowledge on management makes the breed resilient to many drought conditions occurring in Siroua geographical area. Sheep graze a variety of shrubs and herbaceous plants at the rough grazing lands. Additionally, animals are supplemented with cereal grains and straw in case of severe drought or snow. These local practices should be accompanied by a conservation and breeding program to prevent extinction of this indigenous sheep in the future.

Keywords. Sheep – Pasture – Siroua – Management – Climate change – Resilience.

Le savoir-faire local en matière de conduite des ovins marocains de Siroua aide à sa résilience au changement climatique

***Résumé**. Les ressources génétiques animales locales jouent un rôle important dans la promotion de la biodiversité et l'amélioration de la résilience des écosystèmes au changement climatique. Dans le Centre-Est du Maroc, le mouton Siroua est un bon exemple d'adaptation à l'environnement hostile en zone d'altitude (de 1800 à plus de 3000 m) où les précipitations sont très faibles et irrégulières (de 115 à 260 mm par an) et les températures varient de –5 à + 20 °C en hiver et de + 30 à + 45 °C en été. L'objectif de cette étude prospective était de discuter des pratiques mobilisées par les éleveurs et les bergers pour gérer les moutons de Siroua en conditions de changement climatique. Les résultats ont montré que l'alimentation des animaux est principalement basée sur les parcours avec une transhumance entre les pâturages au sommet des montagnes en été et les basses terres en hiver. Ainsi, les connaissances des éleveurs et des bergers en matière de gestion font de la race un élément de résilience à de nombreuses sécheresses survenant dans la zone de Siroua. Les ovins de Siroua sont conduits sur des parcours contenant divers arbustes et plantes herbacées. En outre, une supplémentation en céréales et en paille est fournie en cas de sécheresse sévère ou de neige. Et pour soutenir ces pratiques d'élevage locales, des programmes de préservation et d'amélioration génétique sont nécessaires pour prévenir la disparition de ces moutons indigènes dans l'avenir.*

***Mots-clés.** Ovin – Parcours – Siroua – Conduite – Changement climatique – Résilience.*

I – Introduction

Climate change presents a number of challenges both to livestock rearing practices and to livestock genetic diversity (FAO, 2015). Demand for animal products is foreseen to increase significantly in the near future pushing livestock systems to increase both productivity and efficiency (Boettcher *et*

al., 2015). The challenge is how livestock keepers can take advantage of the increasing demand for livestock products (Thornton *et al*., 2007). The key, to make food-systems climate-resilient, is making livestock systems and grassland use more sustainable to meet improvement of food security, to adapt to climate change and to mitigate greenhouse gas emissions (Hoving *et al*., 2014). Highly productive breeds from temperate regions are not well adapted to high temperatures of south Mediterranean climate (FAO, 2015) and rough grazing conditions. Therefore, livestock genetic resources well adapted, to extreme temperatures, low quality diets and greater disease challenges, are needed to cope with climate change, while increasing food production (Hoving *et al*., 2014).

In Center-Eastern Morocco, Siroua sheep, with about 263,000 heads, is well adapted to an environmental context increasingly impacted by the effects of climate change. This animal genetic resource plays a significant role in promoting biodiversity and improving resilience to climate change. This paper aims to address how the local knowledge on management can strengthen resilience of Siroua sheep livestock system against climate change.

II – Materials and methods

1. The study area

The study was carried out in four sites from Siroua zone located in the Center-Eastern Morocco: *Amassine* (30°47 N, 7°29 W, 2100 m altitude), *Iznaguen* (30°34 N, 7°12 W, 1440 m altitude), *Tislit* (30°45 N, 7°17 W, 1610 m altitude) and *Arg* (30°37 N, 7°27W, 2000 m altitude). The climate is arid, with an average maximum temperature of +35.5°C in July and an average minimum temperature of +0.7°C in January. The mean annual rainfall is 123 mm, with an irregular repartition within the year and from one year to another.

2. Data collection, processing and analysis

Three stations were chosen (Askaoun, Ouarzazate and Sidi Hsain) that represent the geographical distribution of Siroua sheep. Several climatic parameters were calculated from data collected from the three stations for the period of 1985 to 2018. These climatic parameters were the minimal average temperature of the coldest month (m, in °C), the maximal average temperature of the hottest month (M, in °C) and the annual rainfall (R, in mm). In addition, we calculated the pluviothermic coefficient of Emberger Q2(Q2=3.43R/M-m) for the three stations (Stewart, 1968).

To describe the context in which Siroua sheep is reared, some environment descriptors were used according to FAO/WAAP (2008). These indicators, related essentially to climate, agro-climatic zones, soil and vegetation, were summarized from Birouk (2009) and enriched by our own field observations and interviews with breeders. The agro-climatic zone of Siroua sheep was defined according to the classification system provided by Seré and Steinfeld (1996) whose agro-climatic part is based on the length of growing period. In fact, the description of the environment in which a breed is kept over time is one approach to characterize its adaptation; otherwise, this trait is complex and difficult to measure (De Pauw *et al*., 2011).

A field prospection was done at Siroua's area in order to gather all the information available on Siroua sheep since the last reference situation provided by Ezzahiri (1981, 1983) and Ezzahiri *et al*. (1987). In addition, a workshop was organized, with all interested actors (developer, breeders and technicians), around the issue of conservation of animal genetic resources of the Southeastern Morocco, including Siroua sheep. Then a survey was carried out in 20 flocks of Siroua sheep on their management in the current context of climate change. The breeders were interviewed about how they manage their livestock in the current year and what changes are used to apply in a wet year and in a dry year. The main elements considered were herd structure, reproduction, transhumance and feeding, animal guarding and reproduction rates.

III – Results and discussion

1. Environment characteristics

According to pluviothermic coefficient of Emberger (Q_2) calculated for the three considered meteorological stations (Askaouen, Ouarzazate and Sidi Hsain), the climate of Siroua area is arid with a cold winter and a very warm summer. The monthly rainfall pattern is typically Mediterranean, with most of the precipitation recorded between September and March (75 percent). The winter, as determined by the mean temperature of the coldest month, is cold, while the summer, based on the mean temperature of the warmest month, is very warm. The soils are generally alluvial and forests are quasi-missing, except for some light/very damaged forests of the foothills. Lowlands of Siroua's mountains are dominated by white wormwood (*Artemisia herba alba)* and slopes by red juniper (*Juniperus phoenicea*). On the high slopes (between 2,500 and 3,300 m altitude), Birouk (2009) reported that the vegetation is of xerophytic type (*Erinacea anthyllis, Alyssum spinosum, Bupleurum spinosum, Astragalus ibrahimianus*) rich in species with high pastoral and ecological value (*Festuca rubra, Poa bulbosa, Nardu ustricta*).

2. Breed characteristics

Sheep in Siroua area/mountain, located between the High Atlas and the Anti-Atlas (see Environment characteristics above), has been described for the first time by Ezzahiri (1981) as "Siroua breed" with its two main variants, white and black. It formed with Saghro sheep the two main populations of rangedland's system in Ouarzazate Province, with a total census of 600,000 heads (Ezzahiri, 1983). Currently, the white variant is called "White of mountain" (Jannoune and Fagouri, 2011, 2012) while the black one is called "Black of Siroua" (Jannoune and Fagouri, 2012). Its census is about 263,000 heads and it is a small size slender with a body length ranging from 60 to 70 cm, while the rump height range from 55 to 65 cm. Body weight is 25-40 kg for rams and 20-30 kg for ewes (Ezzahiri, 1981). Despite the improvement program carried out by ANOC (Breeders sheep and goat association), body measurements seem to remain invariable as reported by Jannoune and Fagouri (2011) and Kandoussi (2017). In fact, this program, which concern only 152 breeders and 22,000 ewes until now in Siroua's zone, consists of the selection for one color (black or white) in the aim to have more homogenous herds in the future. Interviews with different stakeholders confirmed the social and economic roles of both white and black Siroua sheep for their livelihood through its direct contribution to farm's economy and in the Taznakhte local carpet. In addition to its wool quality, the Siroua sheep is also appreciated for its tasty meat that seems to be linked to the quality of pastures. Lamb carcasses having an average weight of 15 kg, are very popular for family celebrations and official events for the preparation of "*Mechoui*"; a well-known grilled meat in Morocco.

3. Siroua's livestock system

The Siroua's livestock system was largely described by Ezzahiri (1981, 1983) and Ezzahiri *et al*. (1987). Given the environment and breed characteristics described above, Siroua Sheep are housed in highlands during the summer and move between what we call "Azib" or "Azbane (Plural form)". This term, refers to the territory in which the shepherd spends the summer with the flock. Here, the whole family lives in a very modest house, a tent near their herds (sheep and goat), which are kept in the "Tagrourte"; a kind of stone fence. In the winter, the whole family move again with their animals from mountains to zones near their permanent house or "Douar". Generally, the owner himself or one of his sons guards livestock, but we found also collective flock shepherds (recruited by a group of owners) and private shepherds. Ewes always give a maximum of one lamb per year, but in a wet year, some ewes who have given so-called "*Bekri*" lambs (in winter) can give another one in the same year (July-August). Livestock feeding is based on rangelands throughout the year.

Therefore, from October to April, animals exploit collective pastures near settlements. In the summer, collective "*Agdals"* are open for browsing during 5 to 7 months. In addition, grass is collected in the private "Agdal" of each farmer, dried and used to fill the feeding gap observed from October to April. The private "*Agdal"* can also be browsed by sheep from September to October and the entering date depends on the date of the last grass cut. During lambing, ewes receive supplementation based on corn grain, alfalfa hay, grass hay and straw. In case of severe drought, feed supplementation is provided for all the animals.

4. Changes in husbandry practices in response to climate change

In general, Siroua's livestock system has not really changed compared to what has been described by Ezzahiri (1981, 1987) and by Jannoune and Fagouri (2012); it is still based on rangelands. However, some changes can be operated by the breeders depending on the climatic conditions and the vegetation status (see Environmental characteristics above).

A. New transhumance start dates

Generally, early in November, sheep are moved towards lowland pastures near the main residence of breeders. In these rangelands, dominated by wormwood, forbs and grasses, animals spend the entire cold period (December-March). However, if autumnal rainfall is delayed, the journey in the mountains will extended until the first snow (December-January). Similarly, time for moving from lowland pastures to highlands in Siroua's Mountain can be deferred in case of extension of the cold period or the late availability of grass on lowlands. Ezzahiri (1983) already has noted that generally sheep start browsing dried plants in the plains and Saharan zone from October to March or April depending on climatic conditions and vegetation status.

B. Longer transhumance journey

As described in Section 3, the feeding of Siroua sheep is based on rangeland vegetation according to two main movements. One is occurred in April or May, depending on climate conditions, while the herds move to highlands to browse the pastures called "Agdals". Early in the autumn, another move is planned from Siroua's Mountain to lowlands near settlements. These two main transhumances are exercised only within Ouarzazate Province between Mountain pastures, pastures of plains and plateaus and Saharan pastures, as reported already by Ezzahiri (1983). Nevertheless, our survey showed that some breeders, especially from Taznakhte, achieve long transhumance journeys from there to Saharan rangelands (ex. Province of Tata, 29° to 30° N, 7° to 9° W) or subhumid rangelands (ex. Provinces of Agadir and Tiznit, 29° to 30° N, 9° to 10° W). This situation is totally contradictory with was observed in the Middle Atlas by El Aich (2018), who reported a reduction and/or disappearance of herd transhumance in response to reduction of vegetation annual production on rangelands due to recurrent drought.

C. Agriculture and complementation parts in livestock feeding vary considerably

Herds are fed on rangelands all year round both in highlands and lowlands. Moreover, crops, mainly cereals, contribute to animal feeding through exploitation of stubble for one or two months. In addition, grass can be collected from "private rangelands" and dried to be used during the winter. In this period, breeders supplement their animals, since most lambing takes place in winter. Feeds are mainly straw, barley and corn grain. However, some breeders use other industrial by-products like dry beet pulp, wheat bran and composite concentrate feeds. Ezzahiri (1983) has reported that in a wet year, the maintenance of animals is covered only through browsing in the plains and Saharan pastures, but in a dry year, the breeders offer supplements (barley, corn, alfalfa hay, etc.) to their animals. However, our survey showed that the use of alfalfa hay in sheep feeding is almost

absent. This can be explained, on the one hand, by the reduction in the area cultivated for alfalfa in favor of apple tree and saffron, and on the other hand by the allocation of alfalfa for cattle feeding. In the context of the Middle Atlas Mountains, El Aich (2018) showed that other external resources and agricultural by-products (straw, stubble) are offered partially instead of rangelands contributions that make the system heavily dependent on agriculture.

D. Changes in flock size and reproduction rates

In our studied livestock herds, the mean number of ewes per breeder is about 130 ewes, varying from 30 to 225 ewes. This number can be raised on average to 150 ewes in a wet year or reduced to 80 ewes in a dry year. Besides sheep, 75 percent of interviewed breeders have goats in their farms; their census vary from 20 to 300 heads. The lambing rate of sheep varies according to climatic conditions; 0.84 in the year of study, 0.95 in a wet year and 0.52 in a drought year. These results are in concordance with Ezzahiri and El Maghraoui (1983) who reported that, as a result of drought, in1981 and 1982, the lambing rate in sheep fell from 0.82 (1980) to 0.46 (1982). Most lambing takes place between November and January. According to some breeders, in a wet year, additional lambing can take place in summer, and are generally ewes who are mating a second time in March-April. This shows the direct effect of weather and feed availability on ewe prolificacy. Mortality rate of young lambs is about 0.17, but can reach 0.81 when climatic conditions are difficult and vegetation in rangeland is critical. Moreover, in drought conditions breeders relieve ewes of their suckling lambs, by slaughtering them, to reduce their feed requirements to maintenance level. In fact, in winter, which usually matches with the lambing period, keeping sheep alive depends on climate conditions (Ezzahiri, 1983).

IV – Conclusion

Siroua sheep is a small sized animal that lives in (and is named after) the Siroua Mountain between the High Atlas and the Anti-Atlas of Morocco. It is managed according to an extensive breeding/low-input system in which feeding is based on browsing on rangelands. Given Siroua's climate is arid with a cold winter and a very warm summer, some changes are noted in livestock husbandry in response to climate change from one year to another. In this context, breeders modulate time of transhumance between lowlands and mountains depending on climate conditions and vegetation status. In addition, some livestock keepers achieve a long transhumance journeys toward Saharan and sub humid rangelands. This demonstrates that management local knowledge makes the Siroua sheep resilient to many droughts occurring in Siroua area. Its transhumant system provide feeding on various trees, herbaceous plants and shrubs. In addition, supplementation with grains and straw is provided in the case of severe drought or snow for maintaining animals alive. In response, Siroua sheep, which are well adapted for browsing, are able to regain its cruising reproduction rates after a period of drought characterized by a decrease in lambing rate and growth. They represent an important case of sheep resilience to climate change, thanks to successful combination of flexible husbandry practices and a well-adapted indigenous breed. Further investigations of genetic bases under pinning local adaptation and plasticity to harsh climate and low-input breeding system are needed in the near future to elucidate the mechanisms of this resilience.

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Spatiotemporal modification of Mediterranean mountain secondary rangelands by small ruminant grazing

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Abstract. Herbivores impact on vegetation strictly affects the dynamic of landscape patterns in the medium/long-term. In the Apennine mountains (Italy), woodland and rangeland ecosystems are the result of millennia of pastoral and sylvicultural activity. After World War II, Italy witnessed a marked decrease in the number of small ruminants, because of mountain depopulation, lowland agriculture intensification, wool and meat price decrease, etc. This process caused (and is still causing) a degradation of secondary rangelands due to shrub encroachment: undergrazing, low stocking rates and mismanagement generated the loss of grazing surfaces and a reduction of the efficiency of forage utilisation. In the Abruzzo, Lazio and Molise National Park mountain and subalpine belts, we recently identified different areas with diverse grazing management (animal species, stocking rate and grazing pressure). In a selected study area (4,050.46 ha, 1,250-2,228 m a.s.l), characterized by forest, open grassland and forest-grassland mosaic habitats, we performed a land use dynamic assessment in a GIS environment using historical (1954) aerial photos and recent (2017) multispectral images from Sentinel 2 satellites, to assess the different effects of domestic grazing intensity on secondary grasslands inside the forest mosaic and at its outer limit. Results showed that moderate/intense stocking rates are preserving rangelands from encroachment, while very low grazing loads triggered spontaneous shrubland and forest re-expansion. The process was much more marked in grassland-forest mosaic systems than in the landscape features large extensions of continuous grassland sharply bordered by forest.

Keywords. Pastoralism – Mixed grazing – Vegetation mosaic – Rewilding dynamism.

Modification spatiotemporelle des pâturages secondaires des montagnes méditerranéennes en relation avec les conditions de gestion du pâturage des petits ruminants

Résumé. *L'impact des herbivores sur la végétation affecte strictement la dynamique de paysage à moyen/long terme. Dans les montagnes des Apennins (Italie), les écosystèmes de forêts et de pâturages sont le résultat de millénaires d'activités pastorales et sylvicoles. Après la Seconde Guerre mondiale, l'Italie a connu une nette diminution de l'effectif des petits ruminants, en raison du dépeuplement des montagnes, de l'intensification de l'agriculture de basse altitude, de la baisse des prix de la laine et de la viande, etc. En raison de l'empiétement des arbustes: le sous-pâturage, les faibles taux de chargement et la mauvaise gestion ont entraîné la perte de surfaces de pâturage et une réduction de l'efficacité de l'utilisation des fourrages. Dans les ceintures montagnardes et subalpines du parc national des Abruzzes, du Latium et du Molise, nous avons récemment identifié différentes zones de pâturage avec divers modes de leur gestion (espèces animales, taux de charge et pression de pâturage). Dans une zone d'étude sélectionnée (4050,46 ha, caractérisée par des habitats de forêt, de prairies ouvertes et de mosaïque de forêts à prairies), nous avons effectué une évaluation dynamique de l'utilisation des terres dans un environnement SIG, à l'aide de photographies aériennes historiques (1954) et d'images multispectrales récentes (2017) des satellites Sentinel 2, afin d'évaluer l'effet différent de l'intensité de pâturage domestique sur les prairies secondaires à l'intérieur de la mosaïque forestière et à sa limite extérieure. Les résultats ont montré qu'une charge animale modérée/intense préserve les pâturages de l'empiétement, tandis que les très faibles charges ont déclenché une régénération spontanée des arbustes et des forêts. Le processus est beaucoup plus marqué dans les systèmes de mosaïque prairies-forêts que dans le paysage caractérisé par de vastes étendues de prairies continues fortement bordées de forêts.*

Mots-clés. *Pastoralisme – Pâturage mixte – Mosaïque de végétation – Dynamisme de la reforestation naturelle.*

I – Introduction

Many of the mountain habitats in the Mediterranean basin have been created by human activities practiced over several millennia. The most significant were represented by deforestation and shrub removal, in order to increase the extension of grazing land (Ellemberg, 1998; Manzi, 2012). Throughout the second half of the 1900s, abandonment of good pastoral practices were recorded across Europe, leading to a reduction of grazing pressure; and triggering processes of secondary succession of vegetation. The actual dynamics and time-scale of such rewilding processes in the Mediterranean basin are still not well known. We applied a GIS methodology to study the land-use changes occurred in the last 60 years in an Italian mountain landscape (Central Apennine Mts.), in relation to small ruminant grazing.

II – Materials and methods

1. Study area and animal stocking system

This study was conducted in a section of Abruzzo, Lazio and Molise National Park, in the Central Apennines, Italy (Monti della Meta, Picinisco and Barrea municipalities, 4,050.46 ha, 1,250-2,228 m a.s.l). Grassland plant communities mostly belong to *Festuco-Brometea* phytosociological class; communities of *Nardetea strictae* also occur on marly substrata, and *Seslerietea apenninae* primary grasslands can be found at high elevation. Forest vegetation in the study area is almost completely made up of *Fagus sylvatica* woods. The primary subalpine and the secondary shrublands of the montane belt are almost invariably dominated by *Juniperus communis.*

Transhumant grazing of sheep and goats was the main stocking system in the Central Apennines for millennia and it was widely practiced until the 1950s, when ovine grazing started to dramatically decrease (Manzi, 2012). Nowadays, the stocking system consists of extensive co-grazing, involving sheep and goats, but also cattle and equines. The stocking season starts in mid-June and ends in mid-October, and during this period animals have unrestricted and uninterrupted access to pastures. The stocking density varies from 0.2 animal unit (AU) ha^{-1} to 0.8 AU ha^{-1}, in relation to the distance from the pens and from the water sources.

2. Land use change assessment

We defined 9 land use classes: 1-artificial surfaces, 21-arable lands, 311-closed broad-leaved forests, 313-open broad-leaved forests, 314-very open broad-leaved forests, 315-sparse broad-leaved forest, 321-natural rangelands, 322-shrublands, and 323-large areas of 321 with patches of 322. Additionally, we mapped a class named “forest-rangelands patch mosaic with clearings (FRP)”, defined as small open areas (100 m^2 – 1 ha) surrounded by forest and with a Gravelius coefficient < 0.6, a quantitative index of morphometric (shape) characteristics of land use defined as the ratio between the length of the open area boundary (the perimeter) and the perimeter of a circle with the same area.

Land use changes were calculated considering the study period 1954-2017. Land use was firstly defined by manual digitization in a GIS environment, using 800-dpi historical aerial photos (taken in 1954) provided by Istituto Geografico Militare. Images were georeferenced and orthorectified through the Image Analysis tool of ArcMap®. Georeferencing was obtained using the block adjustment photogrammetric technique, locating 10 ground control points in specific places obtained from the 1988 georeferenced orthophotos taken from the Open Data section of the National Geoportal. The Digital Elevation Model (DEM) data was downloaded from the SINAnet ISPRA website (http://www.sinanet.isprambiente.it/it/sia-ispra) and its spatial resolution was 20 m. Considering the

smooth topography of the study area, polynomial transformation was applied in the registration process, and the error related to orthorectification was controlled through the root mean square error (RMSE), which was ±2 m. In addition, in order to eliminate radial and relief distortion, tilt and pitch of aircraft, and scale variations caused by changes in altitude along the flight lines, the photointerpretation was carried out on the central portion of each single frame.

Actual land use was obtain performing a pixel-oriented maximum likelihood automatic classification, using the multispectral images from Sentinel 2 satellites at 10-m cell size resolution (acquisition date: 1 July 2017), available at Copernicus website (https://scihub.copernicus.eu/dhus/#/home). Training sites were selected from Imagery Maps of Google Earth. Accuracy was appreciated by overlapping historical land use, after a proper process of rastering, resampling to a 10-m cell size grid, and a spatially alignment with the Sentinel 2 acquisition grid. Automatic classification accuracy was greater than 79%. An additional classification procedure of land use changes was also performed in order to evaluate the intensity of renaturalization, meaning the transition from a purely anthropic (1-artificial surfaces, class 1) to a wild use (311-closed broad-leaved forests, class 9).

III – Results and discussion

Historical (1954) and present (2017) land uses are showed in (Table 1, Fig. 1 and 2).

Table 1. Transition matrix representing the percent cover changes in the study area for the period of observation (1954 and 2017)

Nomenclature	1954		2017		Var.	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
1-artificial surfaces	1.46	0.0	4.65	0.1	+3,19	+218,5%
21-arable lands	19.36	0.5	8.9	0.2	-10,46	-54,0%
311-closed broad-leaved forests	318.14	7.9	823.57	20.3	+505,43	+158,9%
313-open broad-leaved forests	479.51	11.8	352.63	8.7	-126,88	-26,5%
314-very open broad-leaved forests	121.11	3.0	73.64	1.8	-47,47	-39,2%
315-sparse broad-leaved forest	153.45	3.8	62.47	1.5	-90,98	-59,3%
321-natural rangelands	2834.66	70.0	2562.59	63.3	-272,07	-9,6%
322-shrublands	81.12	2.0	77.51	1.9	-3,61	-4,5%
323-large areas of 321 with patches of 322	41.65	1.0	84.5	2.1	+42,85	+102,9%

The predominant land use is 321-natural rangelands, followed by broad-leaved forests areas. Both the “patch mosaic with clearings” and the “sparse-tree forest” classes evolved towards a closed and dense forest canopy, while the open rangelands have been colonized by *Juniperus communis* shrubland. The most marked change was the increase of 311-closed broad-leaved forests (+505.43 ha, +158.9%), mainly due to the thickening of open and scattered wooded areas (313, 314 and 315 land-cover classes, featuring a 265.33 ha decrease in total). Specific analysis on 321-natural rangelands dynamics, showed that 80.55 ha were eroded by 313-open broad-leaved forests, 66.6 ha by 323-sclerophyllous vegetation, 52.57 by 311-closed broad-leaved forests, 37.68 ha by 314-very open broad-leaved forests, 30.74 ha by 315-sparse broad-leaved forest and 22.49 ha by 322-shrublands. Encroachment of natural rangelands traditionally grazed was more evident in the north of the study area, were grazing load is becoming very low (<0.2 AU/ha) because of difficult access from the towns and is mostly made up of wild ruminants (*Cervus elaphus* and *Rupicapra pyrenaica ornata*) and free-ranging horses. Examples of dynamics from 1954 to recent years are reported in Fig. 2A. In Fig. 2B is represented a transition map, obtained by classification of land use changes according to the intensity of re-naturalization.

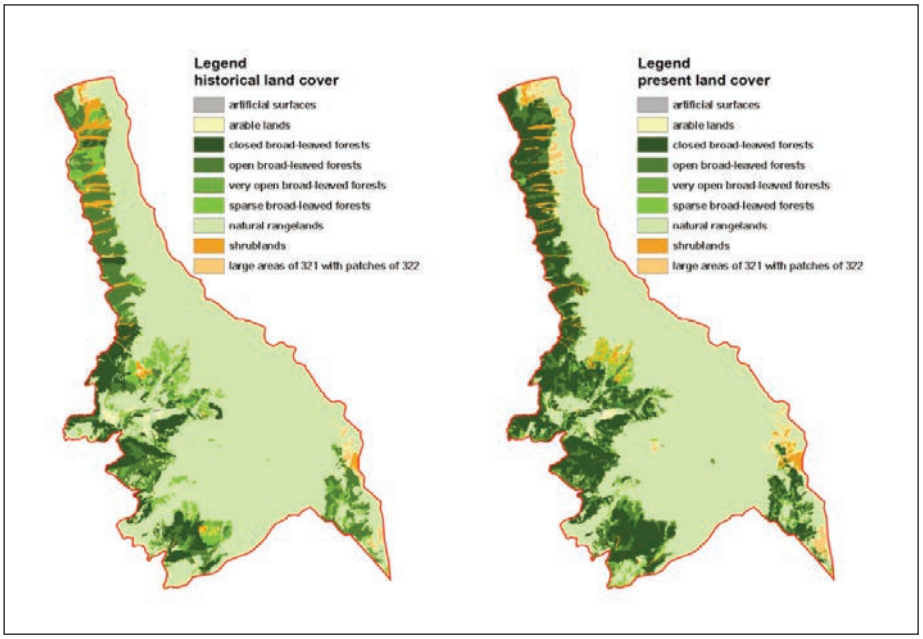

Fig. 1. A) historical land cover – 1954; B) present land cover – 2017.

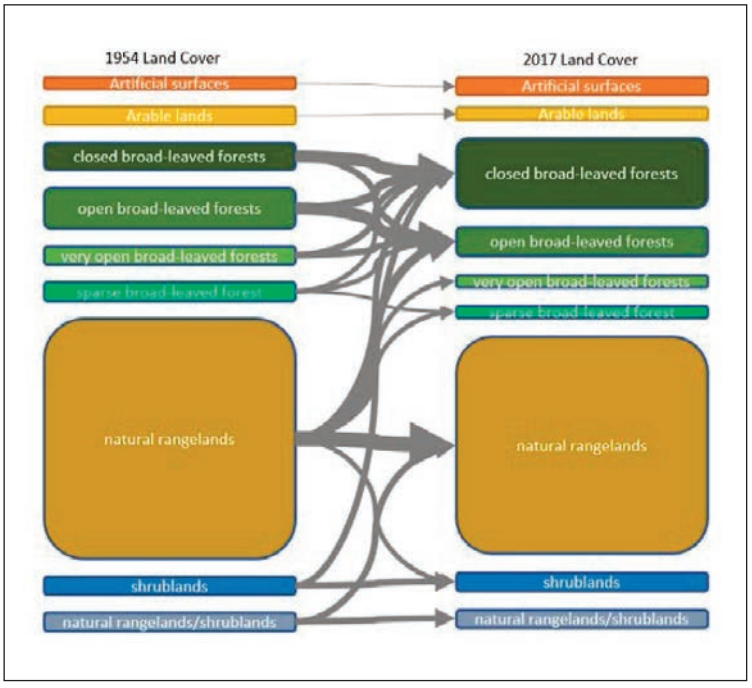

Fig. 2. A) historical land cover – 1954; B) present land cover – 2017.

IV – Conclusions

The rate of loss of open vegetation due to spontaneous reafforestation is strictly correlated with grazing load and pastoralism activities. This process is more marked in the forest-rangeland mosaic areas and in sparse tree forests, probably because of the higher propagule pressure and the microclimate-mediated facilitation processes; while it proceeds more slowly at the outer edge of the forest and in large areas of continuous grassland.

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Factors influencing the adoption of climate change adaptation strategies in the arid Morocco's rangelands

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Abstract. The high plateaus of eastern Morocco (HPEM) have already suffered the adverse impacts of climate change (CC) since it is at the basis of many of socio-economic and environmental transformations observed in this pastoral ecosystem. Moreover, breeder's decision to opt for a particular adaptation strategy among a range of possible choices is dependent on certain factors, which need to be known as they will provide indications of factors that favor or hinder adaptation and they are very useful in developing policies to promote effective and successful adaptation. The objective of this study is to identify the factors influencing the adoption of the main endogenous adaptation strategies. Data obtained through a structured questionnaire from 167 herders selected randomly in the HPEM, were analyzed using binary logistic regression. The main determinants of the adoption of climate change adaptation strategies are perceptual and socio-economic variables. The results of the regressions show that the factors significantly influencing the adoption include perception of long-term change of temperature and rainfall, age of head of pastoral household, education level, training received, size of the flock of sheep, equipment in possession and credit access. Thus, in order to enhance local climate change adaptation, it is suggested to take into consideration these above-mentioned determinants, particularly by setting up some accompanying measures (information, training, financing, equipment).

Keywords. Climate change – Adaptation strategies – Logit regression – Determinants – Morocco.

Facteurs influençant l'adoption par les éleveurs des stratégies d'adaptation au changement climatique dans les parcours arides du Maroc

Résumé. *Les hauts plateaux du Maroc Oriental constituent un écosystème pastoral ayant déjà subi les impacts adverses du changement climatique (CC) puisqu'il est à la base de plusieurs de ses transformations socio-économiques et environnementales. Par ailleurs, la décision d'un éleveur à opter pour une mesure d'adaptation particulière parmi un ensemble de choix possibles est tributaire de certains facteurs, qui ont besoin d'être connus car ils fourniront des indications sur les facteurs qui favorisent ou entravent l'adaptation et ils sont très utiles dans l'élaboration de politiques visant la promotion d'une adaptation efficace et réussie. L'objectif poursuivi est d'identifier les facteurs qui influencent l'adoption des principales stratégies d'adaptation (SA) endogènes. Les données collectées moyennant une enquête structurée auprès de 167 éleveurs, ont été analysées via la régression logistique binaire. Les principaux déterminants de l'adoption des SA sont les variables de perception et socio-économiques. Les résultats des régressions montrent que les facteurs qui influencent significativement l'adoption comprennent la perception d'un changement à long terme de la température et des précipitations, l'âge du chef du ménage pastoral, le niveau d'instruction, la formation reçue, la taille du troupeau d'ovins, l'équipement en possession et l'accès au crédit. Ainsi, afin d'améliorer l'adaptation locale au changement climatique, il est suggéré de prendre en compte les déterminants susmentionnés, notamment en mettant en place certaines mesures d'accompagnement (information, formation, financement, équipement).*

Mots-clés. *Changement climatique – Stratégies d'adaptation – Régression logistique – Déterminants – Maroc.*

I – Introduction

The high plateaus of eastern Morocco are one of the largest pastoral areas in Morocco which have already suffered the adverse effects of climate change (CC). The extensive livestock breeding –main source of income for local populations–, is vulnerable because of its high dependence on the increasingly unfavourable climatic conditions. In order to combat the negative effects of CC, pastoralists in the study area have implemented a range of adaptation strategies. Better understanding of the factors influencing their decision to opt for a particular adaptation strategy, is vital for the identification of the levers of adaptation at the local level. Indeed, the decision of a farmer to opt for an adaptation strategy depends on certain factors such as environmental variables or geographical characteristics, the socio-economic characteristics of households, the characteristics of farms and socio-institutional factors (Below *et al*., 2012; Tiwari *et al*., 2014). These factors whose main determinants need to be studied as they will provide insights into the factors that promote or hinder adaptation (Tiwari *et al*., 2014) and are very useful in developing policies whose purpose is to promote effective adaptation in the agricultural sector (Mabe *et al*., 2014; Berhanu and Beyene, 2015). Thus, the objective of this study is to identify the factors that influence breeders' implementation of endogenous strategies of CC adaptation.

II – Materials and methods

The study was carried out in the high plateaus of eastern Morocco, which are located in the 30S UTM zone. Data collection was done through a structured survey with the heads of pastoral households (a total of 167 herders). The structured questionnaire covered household socio-economic characteristics, perceptions of CC (frequent climate related hazards and risks, changes in rainfall and temperature patterns) and the core endogenous adaptation strategies implemented in response to the perceived climate changes. The household survey was run from September to December in 2015.To identify variables that influence the adoption of the endogenous adaptation strategies, the binary logistic regression was used (Eqn. 1). Giving to Gujarati (2004), the specification of the empirical model of logit regression is as follows: $Y_j = a_0 + a_1x_1 + a_2x_2 + \ldots + a_{35}x_{35} + a_u$ (Eqn. 1). Where: Y_j= the dichotomous dependent variable (breeder practicing any CC adaptation strategy or not, defined as yes=1, 0=otherwise); a_0: the regression constant; $a_1 – a_{35}$: the coefficients of x to be estimated; x_i: the explanatory variables (i: 1,….,35) and a_u: the error term. The explanatory variables used in logistic regression models relating to the adoption of six main endogenous adaptation strategies, include 26 socio-economic variables relating to socio-economic characteristics and assets of households, on and off farm incomes and access to social infrastructure, 2 geographic variables reflecting to the belonging to two different agroecological sub-zones of the HPEM and 7 Perception variables (Perception of: late onset of rains, increased pockets drought, heavy rains, frequent droughts, temperature change, increased violent winds, increased sandstorms). The core adaptation strategies analyzed include: *Herd mobility* in search of favorable rangelands particularly over the droughts of long duration, *Storage of livestock feed* (especially barley) to meet animal needs (essentially food supplementation of lactating ewes), *Regular sale of animals* or decapitalizing strategy which is an anti-risk strategy of the curative type, commonly implemented to overcome the adverse effects of climatic hazards, mainly by small breeders, *breeding of mixed herds* composed largely of sheep and goats, subscription to the *insurance for climatic multi-risks* which has become a common practice, particularly for large livestock producers and to a lesser extent among the medium breeders in order to obtain important financial revenues via compensation in the event of climatic vagaries (drought in particular) and the *Profit of state programs* and interventions such the pastoral improvement actions (fodder shrub planting, tillage), the rangelands' restoration and rehabilitation (resting, seed reserves), the pastoral hydraulics (creation and equipment of facilities of water, micro-dams) and the incentives (Livestock Safeguard Program).

III – Results and discussion

The results of the binary logistic regression analysis are presented in Table 1 which contains only the factors who appeared to play significant role in the decision to adapt to CC. The six logistic regression models obtained have a high quality and strength and allow to classify the observations (herders) successfully since the overall correct percentage prediction rate varies from 78 to 92%. The results show that the breeders' perception to CC affect very significantly the adoption of herd mobility, climate multihazard insurance and profit of state agricultural programs. This suggests that these strategies are targeted responses to CC. Furthermore, since the coefficient of change of temperature perceived is negative and significant for these aforementioned adaptation strategies, thus the breeders' who perceived a change of temperature are less likely to adapt. Debalke (2011) found the same result by showing the negative impact of this factor with respect to the adoption of some adaptation strategies (soil conservation, changing planting dates). Also, the heavy rains perceived is a significative determinant for the adoption of the herd mobility. Berhanu and Beyene (2015) found that this factor is a determinant for pastoral household to adopt the herd mobility as a main adaptation practice.

The results reveal that farmers' who own agricultural equipment and transportation are more likely to adapt to CC. Indeed, the equipment of the farms positively and very significantly affects the adoption of the diversification of livestock species (sheep and goats) and the regular sale of animals to stock up on feed. In line with these findings, Ouédraogo *et al*. (2010) found that ownership of heavy machinery enhances significantly and positively the ability of farmers to adapt in response to CC. Otherwise, the credit access has a positive and very significative effect on the adoption of storage of animal feed but negatively influences the regular sale of animals to stock up on feed. Several authors have pointed out that access to credit is a determining factor in adapting to CC (Obayelu *et al*., 2014; Opiyo *et al*., 2015; Ndamani and Watanabe, 2016). Contrariwise, Piya *et al*. (2013) indicated that the direction of the influence of this factor is negative.

Table 1. Determinants of the adoption of the main endogenous adaptation strategies

Explanatory variables	**Coefficients and signification**					
Adaptation strategies	**Herd mobility**	**Storage**	**Regular sale**	**Herd mixed**	**Insurance**	**State programs**
AAge			-0.07**			-.11***
Education		2.17**		5.67***		
Training	2.43**	-2.78**		-6.12***		2.34*
Sheep Size	0.04**				.024**	
Equipment			1.83**	8.79***		
Credit		4.50***	-1.97***			
Heavy Rain	4.47***					
Temperature					-1.66*	-3.59**
Sandstorm	4.64**				2.88**	
Winds	-3.83*					
Constant	-0.11	-0.08	-0.11	1.26***	-.08	1.33
Correct percentage[1]	88.60	92.20	77.80	91.6	85.6	83.8

Note: Signification: *, ** and ***: Level of significance at 0.1, .05 and .01. [1]: The correct percentage of classification is the number of correct classifications divided by the total number of predictions. it allows to judge the quality and the strength of the model and thus to see if the model successfully classifies the observations (herders).

The results show that the likelihood of older breeders practicing the regular sale of animals and profiting of state agricultural programs is lower than that of younger breeders. Berhanu and Beyene (2015) found that the age is a very significant factor, with negative sign, influencing the pastoral households to prefer herd mobility and diversification of livestock species.

Also, the education level of head of pastoral household positively and very significatively affects the probability that breeders will adopt storage of animal feed and herd mixed in response to CC. In line with these finding, Opiyo *et al*. (2015) consider that this factor is a positive determinant of pastoralist's choices of CC adaptation. In fact, the education level is an important factor influencing the farmers' adaptation to CC (Tiwari *et al*., 2014; Ndamani and Watanabe, 2016). Likewise, the training received by household head has a positive and significant impact on the likelihood of using herd mobility and profit of state programs. However, since the coefficient of training is negative and very significant for the adoption of the storage and the herd mixed, it means that the probability of breeders with training to implement these strategies is lower than that of those without training. Piya *et al*. (2013) and Tiwari *et al*. (2014) emphasize that training improve adaptation to CC. Nevertheless, Yila and Resurreccion (2013) found that the training is a non-significant factor for farmers' adaptation strategies in northeastern of Nigeria.

IV – Conclusions

The main determinants of the adoption of climate change adaptation strategies in the study area are perceptual and socio-economic variables. The access to credit, training, equipment and the education level have a significant effect in the adoption of coping strategies. Public policy aimed to enhance households and pastoral systems' climate resilience should invest in accompanying measures (training, financing) and in the intensification of assets (equipment, incentives), particularly for small-scale herders. Given that these determining factors of adaptation are common to many African countries, it is suggested to consider regional programs implementing similar development strategies focused on improving these factors, particularly in areas where dryland farming is predominant.

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Seed production of native Mediterranean forage species

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Abstract. Sardinian pastures are well adapted to weather conditions of the Mediterranean basin, where the precipitation mainly falls in autumn-winter and absent in summer. Rainfall is the most critical climatic parameter affecting the forage seed yield due to its annual and seasonal variability. For example, in San Michele experimental farm (Southern Sardinia, Italy), the last 4 years rainfall showed significant annual (from 320 to 682 mm) and seasonal variations. These conditions point out the need to identify and develop resilient forage species that are not currently available in the Sardinian seed market. Several years ago, some forage ecotypes were selected from Sardinian pastures biocoenosis. Nowadays, our studies aim to focus on seed production of *Tetragonolobus purpureus* Moench, *Trifolium spumosum* L. and *Medicago scutellata* (L.) Miller, that require different harvesting and selection strategies owing to their specific morpho-physiological characteristics. This paper reports some preliminary data and observations on the difficulty in seed harvesting of these three ecotypes. Results show that harvesting with a common cereal harvester machine has been effective for *Tetragonolobus purpureus* Moench, while unsuitable for *Medicago scutellata* (L.) Miller.

Keywords. Biodiversity – Native forage species – Sardinian pastures – Seed production.

Production de semences d'espèces fourragères indigènes méditerranéennes

Résumé. *Les pâturages sardes sont bien adaptés aux conditions météorologiques méditerranéennes, où les précipitations, concentrées en automne-hiver et absentes en été, sont le paramètre le plus critique en raison de la variabilité annuelle et saisonnière. Par exemple, à la ferme expérimentale de San Michele (Sardaigne du sud, Italie), les précipitations des quatre dernières années ont montré des différences significatives à la fois annuellement (de 320 à 682 mm) et notamment saisonnières et mensuelles. Ces conditions soulignent la nécessité de cultiver des espèces fourragères résilientes qui, pour le moment, ne sont pas disponibles sur le marché des semences en Sardaigne. Il y a plusieurs années, quelques écotypes fourragers ont été sélectionnés parmi la biocénose des pâturages sardes. Nos études sont actuellement destinées à visent la production de semences de* Tetragonolobus purpureus *Moench,* Trifolium spumosum *L. et* Medicago scutellata *(L.) Miller, qui nécessitent des stratégies de récolte et de sélection différentes en raison de leurs caractéristiques morpho-physiologiques spécifiques. Cette étude présente des données préliminaires et des observations sur les trois écotypes concernant la difficulté de la récolte des semences. La récolte avec une machine ordinaire de céréales s'est avérée efficace pour* Tetragonolobus purpureus *Moench, bien qu'elle ne convienne pas pour* Medicago scutellata *(L.) Miller.*

Mots-clés. *Biodiversité – Espèces fourragères indigènes – Pâturages sardes – Production de semences.*

I – Introduction

In Sardinia, native pastures show a high biodiversity (Spanu *et al*.,1997; Vargiu et *al*., 2002) and its botanical species, particularly legumes, as well as feeding livestock, contribute to good agricultural practices (rotations, green manure, grassing) and to multiuse systems (environmental restoring, gardening, honey production, gastronomic, medicinal) (Osman *et al*., 1990).

At present, the forage seed available on the market is expensive and often does not guarantee the expected results. The varieties are not selected for Sardinian pedo-climatic and agro-ecological conditions, where rainfall, generally concentrated in the cold season, is the most critical climatic parameter

given that forage crops are generally grazed in winter and mown for hay in spring. Rainfall presents a high seasonal and annual variability; in San Michele experimental farm located in Southern Sardinia (Italy), rainfall in the last four years registered significant annual differences with respect to the average, ranging from 62% to 135%, as well as an overall seasonal or monthly variability. These conditions point out the need to promote a local seed activity based on forage ecotypes selected from pastures in order to guarantee the availability of resilient Mediterranean species. However, in Sardinia, the low level of forage seeds purchases, amounting to about 5-6 million euros annually calculated on the basis of crops areas (ISTAT), does not seem to justify its economic convenience. Nevertheless, other reasons, apart from the merely economic ones, suggest to undertake seed production activity and its support by the Institutions. First of all, the preservation of territory, considering that Sardinia includes the 25% of Italian pasture, and furthermore the need to guarantee success and ecocompatibility of forage crops and multiuse in the Mediterranean environment.

Several ecotypes locally collected, belonging to different species, are currently under evaluation both for forage and environmental aims (Vargiu and Spanu, 1999; Vargiu *et al.*, 2000; Vargiu *et al.*, 2008; Vargiu and Franca, 2008). To assess the agronomic interest of the ecotypes, it is necessary to consider their capacity for establishment and development, the presence of weeds, the potential yield, the forage quality and the ease of seeds harvesting. As regards the multifunctional interests, it is particularly important to know the different specific characteristics (e.g. habitus, colour of flowers, particularity of legumes, biodiversity). The first evaluations, carried out in different environmental conditions, focused on the traditional self-reseeding legumes (subterranean clovers and annual medics) due to their productive aspects, both quantitative and qualitative. An ecotype of *Medicago scutellata* (L.) Miller proved to be very interesting in terms of its productivity performances. The main obstacle to commercial spreading of these species lies on the difficulty of seed harvest that is performed by suction because the ripe pods fall down to the ground. Our studies focused on species that can be easily harvested with cereals threshers and in particular to the ecotypes of *Tetragonolobus purpureus* Moench and *Trifolium spumosum* L. in order to overcome the difficulties of seed harvesting (Vargiu and Spanu, 2016).

In this context, the current paper reports some *ex situ* observations of these three ecotypes, as regards the biological cycle and in particular the technique of seed harvest that is a key node in the seed production activity.

II – Materials and methods

Seeding of the three local genotypes of *Medicago scutellata* (L.) Miller, *Tetragonolobus purpureus* Moench and *Trifolium spumosum* L. was carried out at San Michele experimental farm (Southern Sardinia, Italy), on November 21, 2014. The site is characterized by a medium-deep soil limited in nutrients except for potassium (typic palexeralf soil, USDA Soil Taxonomy) and Mediterranean climatic conditions. Long term rainfall of 460 mm is distributed from October to May with a large annual and seasonal variability. Winter temperatures seldom reach 0°C, while maximum temperature average is 32°C in July.

The plot size was 10 m^2 with 3 replications. The sowing was done in eight rows 18 cm apart using an experimental plot seeder (Hege 80). The seeding rates are shown in Table 1. During the development, phenological cycle was observed.

Seed was harvested with a cereal combine modified for small seeds (Nutt and Loi, 1999); pods positioned at the lower height of the cutter bar were manually collected.

Seed yield data were not statistically analysed, because of the high differences in the morpho-physiological characteristics (habitat, earliness, pods and seed size) of the three ecotypes.

III – Results and discussion

Biological cycle analysis showed significant earliness differences (Table 1). In the pastures, the different phenological characteristics determine the lengthening of the flowering period, useful for honey production and amenity aims.

Table 1. Seeding density, phenological cycle of the different forage ecotypes and seed harvest date in 2015

Ecotypes	Seeding density kg ha^{-1}	Beginning of flowering	50% of flowering	Full flowering	Harvesting
Medicago scutellata	80 kg/ha	9 April	13 April	17 April	11 June
Tetragonolobus purpureus	80 kg/ha	1 April	5 April	13 April	5 June
Trifolium spumosum	30 kg/ha	23 April	29 April	2 May	11 June

The harvest represents a critical phase of the seed production activity, due to the strategies that the species put into action (prostrate bearing, scalar maturation, spontaneous dissemination) to spread and persist under the Mediterranean conditions and grazing. *Tetragonolobus purpureus* was totally collected by the harvester cereal machine; in the other ecotypes, after harvesting, the residual pods in the field were manually harvested (Table 2) in a variable ratio on the total seed production from 53% (*Trifolium spumosum*) to 92% (*Medicago scutellata*).

Table 2. Seed production (g 10 m^{-2}) collected with harvester and/or manually and number of seeds for m^2

Ecotypes	Harvest machine	Manually collecting	Total weight	% harvester machine	1000 seed weight	Seeds no./m^{-2}
Medicago scutellata	65.0	700.3	765.3	8	19.6	3905
Tetragonolobus purpureus	248.2	–	248.2	100	23.8	1043
Trifolium spumosum	299.7	337.8	637.5	47	1.7	37500

IV – Conclusions

In Sardinia, native pastures represent a seed bank useful for forage and multifunctional aims. A local seed production activity of native forage species could meet the requirement of adapted materials to the Mediterranean environment, for pastures improvement, long lasting forage crops growing and multiuse systems. Moreover, this activity could represent an extra-income for agro-pastoral farms.

Given the current agricultural crisis and the still unresolved seed harvesting technique, it is difficult to start-up a native seed production activity towards as “merely forage species”; instead, it also ought to spread their market by addressing to multiuse systems. Moreover, especially for certain uses (gardening, gastronomic and medical, etc.) the valorisation could requires different packaging from the usual ones and lighter than the classic 25 kg format for sale in agriculture.

Furthermore, the marketing strategies could be useful to support the sustainability of forage seed production from the economic point of view.

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Session 3

Improve the contribution of grazed and cropped forage in the feeding systems

Improving the use of natural and semi-natural grasslands in Mediterranean ruminant systems: issues, options and perspectives

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Abstract. Mediterranean small-ruminant systems (MSRS) have undergone an intensification process triggered by local and global changes. Recent research suggests that such tendency should be reversed. This paper provides insight about how increasing the contribution of grasslands (including natural and semi-natural, improved or temporary grasslands) to the feeding system can improve MSRS' sustainability. Products from grazing animals are ethically appreciated and display good nutritional quality, specific organoleptic characteristics and possibly a longer shelf-life; they can be traced, and thus differentiated. The large surface area of natural and semi-natural grasslands (including areas with shrubs and trees) gives MSRS a head start in terms of carbon sequestration, which can be increased further by an appropriate grazing and feeding management. Technical options to increase grazed grass in MSRS include: (1) producing locally-adapted seed mixtures for grasslands; (2) increasing the proportion of legumes in grasslands; (3) managing grazing in order to maximize the amount and quality of intake; (4) matching the diversity of natural and semi-natural grasslands to animal requirements and/or providing strategic supplementation; (5) reconsidering the value of trees and the interest of foliage as forage. Digital technologies can help to improve farmers' working conditions and build the ecological knowledge necessary to implement adaptive management strategies. At a socio-political level, it is important to recognize the peculiarities of silvopastoral systems, value the ecosystem services provided, foster collective management solutions and facilitate interconnection with other activities.

Keywords. Forage – Grasslands – Feeding system – Management – Animal performance – Product quality – Ecosystem services.

Améliorer l'utilisation des pâturages dans les systèmes d'élevages méditerranéens de petits ruminants : enjeux, leviers d'action et perspectives

Résumé. *Les systèmes d'élevage méditerranéens de petits ruminants (SEMPR) se sont intensifiés sous l'influence de changements locaux et globaux. De récentes recherches suggèrent d'inverser la tendance. Cet article explore comment une contribution accrue des pâtures (naturelles et semi-naturelles, améliorés ou temporaires) aux systèmes d'alimentation peut améliorer la durabilité des SEMPR. Les produits d'animaux pâturant sont éthiquement appréciés et se caractérisent par une bonne qualité nutritive, des spécificités organoleptiques et une durée de conservation accrue ; ils sont traçables, donc différenciables. Les vastes surfaces de pâtures naturelles et semi-naturelles (dont les surfaces boisées ou embroussaillées) sont un atout en termes de séquestration de carbone, qu'une conduite appropriée du pâturage et de l'alimentation peut améliorer. Les leviers techniques pour augmenter le pâturage dans les SEMPR sont : (1) produire des mélanges de graines fourragères adaptés aux conditions locales ; (2) augmenter la proportion des légumineuses dans les pâtures ; (3) conduire le pâturage pour optimiser quantité et qualité ingérées ; (4) faire correspondre diversité des pâtures et besoins des animaux et/ou complémenter de manière stratégique ; (5) reconsidérer la valeur de l'arbre et l'intérêt fourrager des feuillages. Les technologies numériques peuvent contribuer à améliorer les conditions de travail des éleveurs, et à construire les savoirs écologiques nécessaires aux conduites adaptatives. Au niveau socio-politique, il est important de reconnaître les particularités des systèmes sylvopastoraux, valoriser les services rendus, encourager les solutions de gestion collective et faciliter l'interconnection avec d'autres activités.*

Mots-clés: *Fourrage – Pâtures – Système d'alimentation – Conduite – Performances zootechniques – Qualité des produits – Services écosystémique.*

I – Introduction

Pastoral and silvopastoral farming systems, especially when they involve small ruminants, play a major role on both sides of the Mediterranean basin, due to their acknowledged contribution to the preservation of natural resources and the socio-economic development of rural areas (De Rancourt *et al*., 2006; Boughalmi *et al.*, 2015). Their feeding system relies, at least for part of the year, on the spontaneous vegetation grazed by the flock in natural and semi-natural grasslands, which may include woody species (shrubs, trees)[1]. These areas are also a reservoir of biodiversity, with ecological issues related to the pastoral activity (Hadjigeorgiou *et al*., 2005; Mahyou *et al*., 2010). Natural resources, under a Mediterranean climate, are subjected to strong seasonal variations and, at given moments of the annual production cycle, they cannot fully satisfy the animal feeding requirements (in qualitative or quantitative terms). Thus, the farmers need either to move their flock (transhumance) or to resort to temporary grasslands or conserved feed (often purchased, at an additional cost) in order to ensure adequate animal production levels. Silvopastoral systems traditionally use small ruminants (often of autochthonous breeds), which are adapted to such variable and extensive rearing conditions (Cosentino *et al.*, 2014) and apply local know-how to make the best use of the available resources in each territory (PASTOMED, 2008).

In the last decades, Mediterranean small ruminant farming systems (MSFS) have been confronted to major challenges at a global level, related to the increasing uncertainty in markets, policies, climate or changes in socio-cultural trends and consumer concerns (Nori and Scoones, 2019). When farms respond to these challenges with an intensification of their management system in search of higher animal productivity, a concomitant reduction in the contribution of natural and semi-natural grasslands and on-farm resources to animal diets is often observed (example in France: Aubron *et al*., 2016; in Italy: Vagnoni and Franca, 2017; in Morocco: Chattou, 2014). Yet, an increased dependency on purchased feed does not always result in improved economic return or efficiency, as Ripoll-Bosch *et al.,* demonstrated, because self-sufficiency is key to farm resilience, especially when facing uncertain and volatile markets. Furthermore, it certainly fails to exploit the ability of ruminants to convert natural vegetation and human-inedible feedstuffs into high-quality edible protein, which gives them a comparative advantage over other livestock as regards global food security (Herrero *et al.,* 2013).

Today, MSRS are characterized by contrasting intensification levels (Porqueddu *et al.*, 2017), due to factors such as geographical location of farms, contingent market conditions and other external factors such as public incentives or local markets trends (Biala *et al.,* 2007). Alarmingly, Riedel *et al.,* found that intensification was more frequent in farms owned by younger and more innovative farmers, whereas the chances of continuity were critical in those who relied more on grazing resources and applied the most environmentally desirable management strategies. Pastoral farms are generally owned by older farmers, with few or no options for succession (). Besides this intensification process, the population of sheep and goats, most adapted to pastoral environments in Mediterranean areas, has changed significantly in the last decades, decreasing in European countries by more than 25% between 2000 and 2017 (according to FAOstat), mostly due to decreasing consumption trends and low economic profitability, and increasing in Northern Africa mostly due to agricultural policies aimed at improving animal production to meet the growing local demand (Alary and El Mourid, 2005). These trends have led to a degradation of the forage resource on the natural and semi-natural grasslands, either by the combined effect of drought and over-grazing (Morocco: Bechchari *et al*., 2014) or by shrub encroachment (Southern Europe: Bernués *et al*., 2011). Although Mediterranean grasslands have proven to be resilient under different stocking densities and grazing regimes, flexible management systems should be implemented to prevent overgrazing/undergrazing, in a climate change context where their amount and quality will be increasingly unpredictable.

1. The terminology used in this paper is based on Peeters *et al.* (2014).

In order to enhance the development of efficient and sustainable MSRS, research and policies should address the balance between delivering animal products and environmental services, while considering also other challenges such as public health, food security, social equity and animal welfare (Mottet *et al*., 2018). We hypothesize that using more or better natural and semi-natural grasslands in MSRS could be an interesting option to answer and reconcile the three major issues of (i) ensuring the [economic / social / ecological] sustainability of sheep and goat farms, (ii) providing animal products in line with consumers' demand, and (iii) mitigating climate change. The objective of the current paper is to provide insight about how and on what conditions, increasing the contribution of Mediterranean natural and semi-natural grasslands in the feeding systems can be an interesting option for small ruminant farms. The topic is analyzed at animal / paddock, farm and country scales, with an interdisciplinary approach considering agronomic, zootechnical, management and social factors.

II – More grazed grass in the diet: expected outcomes

1. Why extensive grassland-based systems could be more sustainable than intensive ones?

A very large diversity of ruminant farming systems is observed across the Mediterranean area, and while extensification is characteristic of marginal, less-favoured areas relying mostly on natural resources, intensification is common in lowlands where farms have access to forage and grain crops for their flocks (Bernués *et al*., 2011, Porqueddu *et al*., 2017). However, there is also a wide variety of systems within each region, with large differences in the use they make of natural and semi-natural grasslands. Lasseur indicated that the management practices implemented in natural grasslands in French mountain areas depended on the technical, environmental and social concerns of the farmers. In this study, farms specialized as lamb producers differed from those more oriented to pastoral management in aspects as diverse as grassland type (semi-natural vs temporary), grazing management (shepherding vs. fencing), lambing season, lamb fattening system and animal productivity. Similarly, in Spanish meat sheep farms Riedel *et al.* (2007) described in a mountain region the co-existence of intensive production systems (in terms of reproduction rates and indoor feeding) with extensive farms with a large proportion of semi-natural grasslands and, finally, agricultural farms with mixed sheep-crop systems. The latter exploit the complementarity among the available feeding resources (grasslands, forage crops), and allow for a product diversification within the farm that may improve their resilience under uncertain political and socio-economic environments.

Recent studies on key aspects for MSRS' sustainability pointed out the advantages of grassland-based systems. Gutiérrez-Peña *et al.,* analysed the strengths and weaknesses of traditional dairy goat farms and concluded that their viability could be improved: (1) by optimizing the use of grazeable resources, *i.e*. improving semi-natural grasslands, cultivating locally-adapted forage crops and designing year-round feeding schedules to account for forage seasonality; (2) by adopting commercialization strategies linked to the quality of grassland-based products to retain the potential added value. A modelling study on extensive sheep farming predicted higher economic (+40% income) and ecological performance (-29% use of non-renewable energy) for grassland-oriented management strategies (Jouven *et al*., 2011). Application of the changes tested in an experimental farm resulted in a substantial increase in feed self-sufficiency (Jouven *et al*., 2015a). Feed self-sufficiency seems to be an effective way to increase farm sustainability, mainly in less-favoured areas. An agro-ecological survey carried out by Thénard *et al.* (2016) showed that farmers could improve farm self-sufficiency through different strategies, as a result of a trade-off between production, purchases and the use of local resources. In any case, each self-sufficiency pattern should be assessed in relation to environmental issues. Agroecological transition requires a good knowledge of the practices required to face the constant disruptions of the system (climatic hazards, pre-

dation, …) and reduce environmental impacts. Adequately managed livestock can also be a tool for the efficient management of areas with high natural value, sustaining at the same time a viable economic activity and providing differentiated products that fulfill societal demands for quality and environmentally-friendly production.

2. What can be expected out of a diet of Mediterranean forage in terms of product quality?

The effects of a grassland-based diet depend on a variety of factors such as the physiological status of the animal, the type of forage (main species, maturity, chemical composition) and feeding management (grazing vs. preserved, stocking rate, availability of supplements), among others.

High rates of forage inclusion in ruminant diets may result in a different product quality in terms of chemical composition. Ruminant products are usually low in fat but have a higher proportion of saturated fatty acids than other animal species, because dietary fat is partially biohydrogenated by ruminal microorganisms while they cannot synthetize polyunsaturated fatty acids (PUFA), the main source of which is green forage. Therefore, the fat composition of end products depends on the fat composition of the ingested diet and the rate of ruminal biohydrogenation, which can be partially inhibited by plant secondary metabolites. Cabiddu *et al.,* found that the forage species and its phenological phase influenced the concentration of fatty acids with beneficial effects on human health in the milk and cheese of dairy sheep (mono- and poly-unsaturated fatty acids, conjugated linoleic and vaccenic acid). Higher concentrations of those fatty acids were found for ewes grazing pure legumes or grass-legume mixtures than for ewes grazing pure grass swards, especially in the vegetative (rather than in the reproductive) stage. Similarly, Joy *et al.,* found that grazing improved the contents of conjugated linoleic and vaccenic acid and the PUFA n-6/n-3 ratios in sheep, compared to a hay-based diet. This was observed both in the milk produced by the ewes and in the meat of their suckling lambs, since young lambs are functionally non-ruminants and dietary fatty acids are transferred into their tissues in their original, non-biohydrogenated form. These differences in meat quality were even used as a basis to accurately discriminate among different feeding systems.

Grazing can also affect sensorial properties of ruminant products. In the case of dairy animals, higher PUFA contents in milk reduce fat melting point, resulting in cheeses of a softer, more melting texture. Some grassland components as terpenoids (abundant in forbs) and carotenoids (which decline with herbage maturation) are directly transferred from herbage to milk. The former are responsible for cheese odours and aromas, and the latter for its yellow colour. In the case of meat, comparisons between grassland-based and concentrate-based feeding systems generally show a more yellowish fat, due to the deposition of grass carotenoids, and a darker meat colour in grassland-fed animals, due to factors such as ultimate-pH, intramuscular fat content and composition. These colour traits can be used as markers for the traceability of grassland-feeding (Blanco *et al*., 2011), although the accuracy of classification can be limited if animals are finished indoors after grazing, because of their intermediate meat and carcass characteristics (Casasús *et al*., 2016). A pastoral flavour originates mostly in the oxidation of grass linolenic acid in the case of cattle and the deposition of skatole in sheep (Priolo *et al*., 2001), the ruminal biosynthesis of which can be limited by dietary tannins. These phenolic compounds, together with other secondary metabolites like saponins or essential oils, can also influence meat flavour or oxidative stability, by reducing discoloration and extending meat shelf life. In this sense, Lobón *et al.,* indicated that meat lipid oxidation was lower in lambs raised with their dams at pasture than in lambs raised indoors, especially when ewe-lamb pairs grazed on sainfoin rather than on alfalfa temporary grasslands. This was associated to the higher ! -tocopherol and condensed tannin contents of sainfoin as compared to alfalfa, which resulted in a meat shelf-life 4 to 6 days longer.

In the food market, consumers care about production chain sustainability, authenticity and responsibility, personalisation and health & wellness (Poore and Nemecek, 2018). Ruminant systems

based on a high use of grazed forages and legumes benefit from the effects on sensorial and instrumental quality traits of the meat and milk obtained in these conditions. A quality-based differentiation together with the strong territorial link of these products, very important for consumers, could be the basis of specific product differentiation schemes. These programs add value to animal production and increase its marketability, making them attractive for all stakeholders within the supply chain, from farmers and retailers to consumers.

3. What is the potential of grassland-based systems in terms of climate change mitigation?

The greening process of agriculture and livestock sectors is supported by EU climate change policies and driven by the increasing demand of environmental-friendly agri-food products. Reduction of greenhouse gas (GHG) emissions from ruminant farming systems in order to mitigate climate change can be done either by increasing carbon (C) sequestration or by reducing carbon emissions in the form of methane (CH_4). The Mediterranean livestock supply chain is a good example for exploring the relationship between small ruminants farming and climate change (Marino *et al*., 2016).

Grazing management and the total surface area of natural and semi-natural grasslands (including areas with shrubs and trees) are the characteristics that affect potential soil C sequestration the most (Bernués *et al*., 2017). Correct agronomic practices may increase soil C sequestration, especially in extensive small ruminant farms, where permanent grasslands plays an important role as C sink (Hopkins and Del Prado, 2007). Natural and semi-natural grasslands improve soil C stock with respect to arable crops, due to a higher stability of C returning to the soil and to an increased residence time of C in the absence of soil tillage (Soussana *et al.,* 2004). Grasslands cannot sequester C indefinitely in time. Thus, grazing management can improve soil C sequestration, by regulating the grazing pressure both in overgrazing/undergrazing conditions (Vigan *et al.,* 2017). However, the effect of grazing regimes on the GHG emissions is still unclear. At farm scale, increasing the contribution of natural and semi-natural grasslands in small ruminant systems might have other positive side-effects, such as improvement of the overall environmental performance, with a better eco-efficiency due to less mechanized operations and to a lower use of inputs, thus reducing eutrophication, acidification, GHG emissions and non-renewable energy use (Rotz *et al.,* 2010; Soteriades, 2016; Vagnoni and Franca, 2017).

Dietary mitigation strategies, through the increase of diet digestibility, are crucial to mitigate CH_4 emissions. Methane emissions can be limited by increasing forage quality, either by feeding ruminants high quality forages such as legumes, and/or by adopting grazing management techniques aimed at securing a high quality of grazed forage (LEAP, 2019). Though, increasing forage digestibility is no trivial matter, since digestibility varies among forage species and plant parts and changes depending on standing herbage mass, phenology, cultivation techniques and grazing management. Usually, legumes are more digestible and ingested in higher amount than grasses at an equal growth stage (Rochon *et al.,* 2004). Legume and forb species may differ significantly in the digestive CH_4 and nitrogen (N) release due to differences in the content of bioactive compounds such as tannins and saponins (Waghorn *et al.*, 2002; Archimede *et al* 2011). Also, grasses and legumes with high content of water-soluble carbohydrates may contribute to the reduction of CH_4 emission, having the potential to reduce ammonia escape from the rumen and to increase intake and performance (Lee *et al.,* 2001; Jones *et al*., 2014). Grazing management may be a relevant mitigation strategy when adopting specific grazing management solutions, such as rotational grazing, in order to limit the digestibility decay related to herbage mass accumulation - or a part-time afternoon grazing that may enhance ruminant intake and performance, through a more efficient rumen N incorporation (Gregorini, 2012; Molle *et al.*, 2016). The options reported in this paragraph are easier to implement in temporary grasslands, but they could also find applications in pastoral systems, where flock mobility can enable to “follow forage quality and availability in space

and time". The high heterogeneity observed in the effectiveness of mitigation strategies (Veneman *et al*., 2016) calls for a deeper knowledge about the technical applicability of strategies within specific production systems and about the economic implications of their implementation.

III – Technical options to increase grazed grass in Mediterranean feeding systems

1. Innovations to improve the amount and quality of forage production in grasslands

The agrarian landscape in the European Mediterranean regions appears as a complex mosaic of feed resources, animal species and local breeds, as an effect of the local socio-cultural traditions (Porqueddu *et al.,* 2016a). Grazed forage crops represent a relevant portion of this mosaic (EIP-AGRI Focus Group on "Permanent grasslands", 2014). The influence of climate change is expected to lead to large reductions in Mediterranean crop productivity with increased water demand, hastened maturation and reduced yields for spring crops and geographically variable effects for autumn crops (Maracchi *et al*., 2005; Rötter and van de Geijn, 1999). Innovation aimed at improving forage productivity, compatibly with the eco-sustainability of animal production, needs to face such climatic trend. Also, farmers increasingly ask for locally-produced feeds adapted to the particular soil and climate conditions of each area, especially if they can be used under direct grazing systems and have long vegetative periods. This interest concerns especially forages, but also local grains, oil seeds and pulses as an alternative to reduce the dependency on soybean imports.

Regarding temporary grasslands, annual forage crops such as traditional mixtures of annual forage legumes (common vetch, woolly pod vetch, Persian clover, crimson clover and berseem clover) and winter cereals (oats, barley and triticale) or grasses (especially Italian ryegrass: *Lolium multiflorum Lam.* ssp. *italicum* and ssp. *westerwoldicum*) are used for short-term forage crops on arable lands (Porqueddu *et al*., 2017). They are usually grazed up to the end of winter and left ungrazed for all the final growth cycle in spring, when they are cut for hay production. Mixtures based on annual self-reseeding legumes and winter cereals have been introduced to extend the duration of temporary grasslands to two or three years. Among perennial forage crops, alfalfa represents the primary temporary grassland species for neutral and alkaline soils, while other perennial legumes as red clover and birdsfoot trefoil are less frequently sown. A renewed interest is growing for sulla and sainfoin (Re *et al.,* 2014). A few varieties of perennial grasses, particularly cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.) and bulbous canary grass (*Phalaris aquatica* L.), are sown in higher rainfall areas with deeper soils and they are generally included in seed mixtures with annual or perennial legumes.

Regarding semi-natural grasslands, the species and varieties of legumes and grasses to be used in mixtures sown at the establishment of the sward should be accurately chosen. Traditionally, self-reseeding annual legumes, in particular subterranean clover and annual medics, have been used for the improvement of semi-natural grasslands in many European Mediterranean areas. However, these cultivars are often poorly suited to the climatic conditions and management systems of southern Europe (Sulas, 2005; Porqueddu *et al*., 2010). In more recent years, some innovative annual legume species suitable for soil types and farming systems not suited to annual subterranean clover and medics have been developed. Among these, biserrula, yellow serradella, French serradella, balansa clover, arrowleaf clover, bladder clover and Persian clover (Nichols *et al*., 2007).

Innovation for forage productivity necessarily needs multidisciplinary investigations on the different types of grazed forage crops and plant species components related to the quality and value of livestock products. Self-sufficiency in high-protein feeds is a challenge (Porqueddu *et al.,* 2016b). A suc-

cessful development of legume species and varieties well-adapted to Mediterranean habitats is needed, both for temporary and permanent grasslands. The available seeds for temporary grasslands are selected and multiplied in various countries including Central Europe, Denmark and New Zealand. Seed production also occurs in Italy and France but is mainly restricted to alfalfa (Huyghe *et al.,* 2014). Annual legumes for the improvement of semi-natural grasslands are selected, multiplied and imported mainly from Australia. The seed market of such varieties thus mainly relies on Australian seed companies (Loi *et al.,* 2008). However, these varieties show often poor adaptability to the variable climatic and management conditions of southern Europe (Sulas, 2005; Porqueddu *et al*., 2010). Thus, there is a need to develop local seed production in the Mediterranean basin.

2. Feeding and grazing management to improve animal performance

Grassland-based feeding is often associated with lower animal performance compared to stall-feeding. The main reasons for this would be a lower quality of the feed ingested, a variable availability of the pastoral resource and a higher energy expenditure for walking and regulating body temperature. Recent research suggests that these arguments are not always true, depending on the seasons and local conditions, and points out possible solutions to improve animal performance at pasture.

Mediterranean legume-based grasslands, particularly those containing moderate levels of condensed tannins, like sainfoin (*Onobrychis sativa*), sulla (*Hedysarum coronarium*), chicory (*Cichorium intybus*) or birdsfoot trefoil (*Lotus corniculatus*) have been reported to improve sheep performance. This benefit has been ascribed to increased intake and N retention, reduced methane emissions and improved resilience to digestive parasites, among others. A combination of these forages with annual grasses can provide an adequate protein:energy ratio in grazing dairy sheep, that could be fully balanced with fibrous concentrates in some phases of lactation (Molle *et al*., 2008). Accordingly, Gutiérrez-Peña *et al*. (2016) indicated that concentrate supplementation for dairy goats grazing on semi-natural grasslands and forage crops could contribute as much as 57% of the total annual herd energy requirements, in order to compensate for forage seasonality and to obtain optimum milk yield. In the case of meat sheep in Mediterranean mountain areas, Gonzàlez-Garcìa *et al.* (2014) reported that suckling *Romane* ewes grazing natural grasslands in spring performed fairly well, with an average daily gain around 200g/day for twins and 250g/day for singleton lambs, and no loss in body condition score for ewes, apart for multiparous ewes suckling twins (-0,2 points /5). Joy *et al.,* showed that lamb performance was improved when their dams grazed on natural grasslands compared to when they received indoors hay from similar canopies (0.26 vs. 0.22 kg/day). However, due to the seasonality of forage growth in these conditions, this management could only be applied during the vegetative period in spring and for a short period on the autumn regrowth.

In order to overcome seasonal drops in grazeable resources, integration of forages with longer vegetative growth periods such as alfalfa (*Medicago sativa*) in the grazing plans has been proposed. Alvarez-Rodríguez *et al.,* described that light lambs reared by their mothers on alfalfa with creep-fed concentrate supplement until slaughter had similar gains to weaned lambs fed with *ad libitum* concentrates in feedlot conditions (0.24 vs. 0.26 kg/day, NS). The long growth period of alfalfa would allow for this management for ewes lambing in spring and summer. Similarly, Blanco *et al.,* indicated that rotational grazing of young bulls on *Medicago sativa* supplemented with 1.8 kg DM barley/day provided an interesting alternative to feedlot concentrate feeding. This system allowed for a 165-day grazing period with daily gains similar to those obtained at the feedlot (1.36 vs. 1.52 kg/day, NS) but at a lower economic cost per kg gained. Other studies, however, found lower growth rates in cattle fed forage-based diets, maybe due to a higher energy expenditure at pasture or to a suboptimal nutrient synchrony (carbohydrate:protein) in absence of adequate supplements.

In practice, if natural grasslands (including areas with shrubs and trees) usually meet the low requirements of dry females, high-quality rations are needed for dairy ewes or lambs. Those can be

obtained either by grazing high-quality, immature swards of natural or semi-natural grasslands in spring or autumn, by introducing improved grasslands in the forage plan (or in the daily grazing circuit in case of shepherded flocks), or by strategic supplementation at pasture. In all cases, a fine-tuning in the choice of the grasslands and of the supplements is needed in order to fulfill the animal requirements while maximizing the intake at pasture and thus minimizing feeding costs.

3. Management options to make the best use of natural and semi-natural grasslands

Natural grasslands provide low-cost grazed forage in many MSRS, and sometimes have a very high contribution in the feeding system. Jouven *et al.* (2015b) found, based on farm surveys, that natural grasslands could provide up to 80% of the feed ingested by young horses and mares in Endurance and Camargue farms of southern France. A better use of natural grasslands is thus a key to improve the technical and economic performance of MSRS. This implies an optimum integration in the grazing calendar, either by grazing them in the periods where their yield and quality is at its highest, or by using them in other phases with animals of limited nutritional requirements. Tuning the dynamics of animal requirements and forage availability will sometimes require adapting animal management in terms of calving and weaning dates.

Taking advantage of the diversity of natural grasslands and of the complementarities between natural and temporary grasslands is another key point. In dry mountain areas of Spain, autumn-calving cow-calf herds could graze throughout the year in a combination of wooded and dry grasslands, supplemented in periods of scarcity with forage (winter) and forage crops (summer). Brosh *et al.,* described that when adequate supplements were provided at given periods, pregnant, lactating and dry beef cows could meet 80% of their energy requirements in Mediterranean wooded grasslands, where browse constituted up to 60% of the diet in periods of low grass availability. Shrubby vegetation plays a major role as forage resource for small ruminants during the summer drought, although the intake of foliage can be limited for many Mediterranean plant species due to the presence of secondary compounds which may impair animal health. These effects can be counteracted by supplementing animals with additives that decrease their absorption and/or increase their elimination. For eastern Morocco, Gobindram *et al.* (2018) reported a strategic utilization of natural grasslands, wooded grasslands and cereal stubble depending on the season and on their local availability; where wooded grasslands were common, farmers would keep more goats in the flock in order to take best advantage of the available foliage. At smaller scales, experienced shepherds would offer a diversity of feeding sites during the daily grazing circuit, as previously reported by Meuret and Provenza (2015). In fact, the diversity of feed items, both in terms of quality (Silue *et al*., 2016) and in terms of bite size (Agreil and Meuret, 2004), makes it possible for the animals to adjust their feeding choices and secure the amount and quality of their intake. In order to do this, the domestic herbivores need to learn, especially in their young age and by observing the behaviour of their mother, the nutritional interest of plant parts and associations of those plant parts (Meuret and Provenza, 2015). Thus, replacement females should be raised at pasture, ideally with their mother.

Making a sustainable use of natural grasslands implies ensuring the renewal of the pastoral resources on the long term, and thus controlling vegetation dynamics. Grazing by both sheep (Riedel *et al.,* 2013) and cattle has proven to affect vegetation dynamics on Mediterranean natural and wooded grasslands. However, although they consumed herbage biomass and maintained a stable cover through the years, stocking rates may not be high enough to prevent shrub encroachment and its detrimental effects on environmental risks (loss of diversity, fire hazard). This would call for specific actions either through enhanced grazing management or by means of prescribed fire and mechanical removal for controlling shrub invasion. The efficiency of these methods for the recovery of grasslands will depend on the biology of the dominant species and the establishment

of an adequate grazing pressure afterwards that can ensure both grass seed dispersal and shrub regrowth control. In Southern Mediterranean areas, where natural grasslands tend to be overgrazed, different strategies have been recommended to reduce grazing pressure and foster rehabilitation. Among them, Ates *et al.,* proposed the use of natural grasslands with fodder crops, by introducing forage legumes into rotations with cereal crops or by intercropping fodder trees or shrubs in the fields, and the optimization of grazing rotations on *wadis* and lowlands to enhance their productivity and nutritive value for livestock.

Rangelands are economically interesting for the farmer not only as a forage resource but also because they allow to minimize mechanized operations; though, they usually require fencing or shepherding, which can be costly and tough to implement. Besides, grazing the flock on large areas with bushes and trees might increase the predation risk (Nozières-Petit *et al.*, 2017). The conservation of open pastoral areas by extensive livestock systems provides a wide range of ecosystem services, each influenced, to a different extent, by numerous agricultural practices. Fire prevention is the most publicized ecosystem service in North Mediterranean areas, and several wildfire prevention programs include extensive grazing in forests or specifically on fuel breaks, often under payment schemes based on a long-term commitment of farmers and public administrations. A payment system based on farmers' agricultural practices and their associated benefits extended to other services would ensure that farmers are fairly rewarded from society for their contributions, and motivate them further to use natural grasslands.

4. Efficient and sustainable management of silvopastoral systems

Silvopastoralism indicates the association, in the same piece of land, of silviculture and livestock grazing. Silvopastoral systems cover a total of approximately 20 million ha in the EU27 (4.7%) and about 10.8% of the Mediterranean biogeographical region. Silvopastoral systems involve grazed wooded grasslands and are particularly relevant in Mediterranean countries: Dehesas in Spain and Montados in Portugal occupy about 7 million ha; Greek Phrygana, a maquis managed by grazing and occasional fires, concerns more than 1 million ha; in Italy, 1.3 million ha (10% of the utilised agricultural area) integrates trees with livestock production (Riguiero-Rodríguez *et al.*, 2009; Moreno *et al.*, 2014; Paris *et al.*, 2019). Silvopastoral systems have an exceptional ecological value as a result of their contribution to biodiversity at a landscape level, their dynamic character, and their role as a repository of genetic resources (Plieninger *et al.*, 2015). They also enable to increase the total production on a given surface area, thus contributing to the ecological intensification of agriculture, and have an important socio-economic role, providing rural employment and a range of ecosystem services (Seddaiu *et al.,* 2013; Rossetti *et al.,* 2015). In a context of serious risk of inland abandonment, silvopastoral systems require a new management approach in order to enhance and value their multiple functions.

Trees and livestock can be combined with semi-natural grasslands to form an integration of animal husbandry, silviculture, and forage crops, defined as "silvopasture" (Sharrow *et al.*, 2009). The innovative management practices associated to silvopastures are related to grazing regimes and forage production. Traditional grazing management practices often involve an intense grazing pressure, which may compromise tree regeneration (Moreno *et al.*, 2014). In the framework of the LIFE Project REGENERATE (www.regenerate.eu), adaptive multi-paddock grazing management is being tested. The principle is to take into account ecosystem complexity to plan the distribution of grazing over time, across landscapes and plant communities, using a series of paddocks (Teague and Barnes, 2017). In addition, multi-species grazing tries to optimize the complementarities among the feeding behaviour of sheep, goats and cattle in the framework of rotational grazing.

The needs of silvopastoral farmers were assessed with a survey in the framework of the AGFORWARD Project (www.agforward.eu). Priority was given to enhancing the availability of forage re-

sources in the understory layer, to improving the valuation of grassland resources, and to increasing grassland productivity and quality (Pisanelli *et al.,* 2014, Camilli *et al.*, 2018). In non-arable lands, such as natural or wooded grasslands in the mountain areas, livestock usually graze extensively, mainly during spring-autumn months, when fodder resources in the plain are scarce. For deep enough and arable soils, a more intensive management could be possible in silvopastures, with the sowing of high quality forage species and a targeted mineral fertilization, especially in terms of phosphorus, which enables to extend the period of grass growth and thus the length of the grazing season and favours the development of legumes which improve the nutritive quality of grazed forage. In silvopastures with shrubby vegetation, mechanical clearing can be associated with fertilization and, if necessary, over-sowing of adapted pasture species with techniques of minimum tillage or sod-seeding. In case of degradation of the herbaceous layer with invasive species, overseeding and fertilization can help restoring the sward, provided the seed mixtures are adapted to the local environment (annual self-reseeding clovers and medics in dry areas, perennial grasses and clovers in soils with high water retention capacity). Unfortunately, the seed market does not provide specific shade-tolerant pasture species. Recently, a research aimed at selecting shade tolerant pasture legume species for silvopastoral farms was carried out by Franca *et al.* (2018). The preliminary results indicated *Trifolium subterraneum* L. var. Campeda, *Ornithopus sativus* Brot. var. Cadiz, *T. vesiculosum* Savi and *Medicago polymorpha* L. var Anglona are the most promising species.

Although silvopastoral systems have proven to be sustainable, and efficient management practices are being designed, they suffer from a poor recognition by the EU Common Agricultural Policy (CAP), which considers them as a specific agroforestry practice only since about ten years. Until now, the application of specific measures supporting silvopastoralism in EU countries has failed. Thus, each member state should contribute to the effective application/adoption of the existing measures, in order to account for the peculiarities of the silvopastoral systems in each country.

IV – Social, technological and territorial perspectives

1. Social factors determining an efficient and sustainable utilization of natural grasslands

As a consequence of livestock systems' intensification, the function of natural grasslands (including areas with shrubs and trees) in the feeding systems has changed: often, they are no more the main feed resource, but instead they are viewed and used: (a) in Northern Mediterranean areas, as a security in case of climatic hazards or as a low-cost forage resource for animals with low feed requirements (Jouven *et al*., 2010) or (b) in Southern Mediterranean areas, as a place where the flock can have access to a water point (Bechchari *et al*., 2014; Gobindram *et al.,* 2018). In both cases, the management practices implemented are not aimed at conserving the pastoral resource anymore, but rather at taking advantage of a low-cost source of [low quality] forage.

The status of natural grasslands determines the interest and implication of users for their sustainable utilization. In South Mediterranean areas, natural grasslands are community lands, traditionally governed by tribal rights. The addition of colonial and post-colonial rules created a confusion in the user rights, paving the way to an opportunistic utilization, incompatible with the long-term renewal of pastoral resources (Bourbouze and Gibon, 1999). The richest farmers, who own trucks and can easily move their flock around, and the most influential social fractions, exploit intensively the best pastoral resources (Bechchari *et al.,* 2014). In France, the Pastoral Law of 1972 created a favourable legal context for the development of pastoralism, with 3 complementary tools (Charbonnier, 2012): the multiannual pastoral convention (CPP, a contract between land owner and pastoral farmer for a seasonal utilisation), the pastoral group (GP, an association of pastoral farmers using a given area of rangeland) and the land pastoral association (AFP, an association of land own-

ers putting together their land for a given pastoral use). As a consequence, two situations co-exist in terms of access to rangeland (Gava *et al.*, 2018): (a) in lowland areas where livestock activities had until recently almost disappeared and land speculation is common, farmers have a precarious access to natural grasslands (oral or no agreement with the [private] land owner), making it difficult to obtain CAP subsidies and reducing the investments in pastoral developments; (b) in upland areas, where extensive livestock systems have always existed and ecological and recreational issues are associated with grazing, farmers have a secured access to natural grasslands (ownership, agricultural lease, CPP with public body), often associated with collective bodies (AFP, GP) which make it possible to implement pastoral developments and hire shepherds. In Mediterranean areas, there is a need for legal tools, co-constructed with the local populations, which can regulate the utilization of natural grasslands and encourage the user communities to co-construct and implement a sustainable grazing management (Ait-Alhayane, 2016). Since mobility and cooperation are vital for the resilience of pastoral systems, collective management solutions are to be preferred.

The contribution of natural grasslands to the feeding system (in terms of % of forage consumed by the flock) is widely influenced by two factors: on the one hand, the available surface area of natural grassland and the vegetation diversity; on the other hand, the global production strategy of the farmer, and especially his willingness to feed animals with high requirements on natural grasslands. Lasseur (2005) classified French Mediterranean sheep farms into three classes: (a) the “lamb producers”, with a controlled and more intensive production of lambs fattened indoors, who only use rangelands to feed dry ewes, a few months a year; (b) the local pastoral farmers, whose typical agropastoral systems are based on improved forage and who use alpine grasslands through transhumance, but also locally available natural grasslands when improved forage resources are unavailable; (c) new pastoral farmers, grazing all the flock on natural grasslands, through frequent mobility and shepherding. Jouven *et al.* (2015b) classified horse pastoral farms in Southern France on the basis of the contribution of natural grasslands to the feeding system; the most pastoral farms were those who had a secure access to large surface areas of natural grasslands and who grazed all animal categories there (from young horses to lactating mates), with little or no supplementation. Generally, farmers who supplement systematically grazing animals lack confidence in the ability of natural grasslands to provide the necessary nutrients. Such farmers also tend to keep indoors the animals deemed as “fragile”, such as lambs and young replacement females, thus preventing them from learning to forage (and more generally behave) in a diversified and variable environment.

The efficient use of natural grasslands implies adapting a wide range of management practices in order to make the best use of animal and plant diversity, and to compensate for the unpredictable environmental changes. Such adaptive management is based on a close monitoring of the system, associated with a good knowledge of grassland ecology and of grazing animals’ behaviour (Meuret and Provenza, 2015). Traditionally, such local ecological knowledge (LEK) was acquired by observing (while shepherding) the state of the grasslands and the behaviour of the flock, their changes during the days and seasons, and their response to new management practices. With the decline of shepherding (less shepherds + depreciation of the job), the amount of LEK held by farmers is decreasing (Gobindram *et al.,* 2018). A challenge is thus to value LEK and find new ways to pass it from one generation to the next, but also enhance it with individual experiences and scientific knowledge.

2. Technologies to overcome cognitive and informational obstacles

In less favoured areas, farm viability not only depends on technical and economic efficiency, but also on environmental and societal dimensions. Concerning the social pillar, despite extensive farmers are reasonably satisfied with their job, other issues are more controversial, *e.g.* there is a clear lack of generational turnover, probably linked to the low attractiveness of the job for young farmers, the arduous work and living conditions in rural areas or the lack of acknowledgement of their role by society. In order to maintain farming and population in rural areas, increasing the job at-

tractiveness along with farmers' income should be a priority for policy makers. Technologies related to smart precision farming can help promote the activity in marginal areas.

Precision livestock farming (or "smart farming") uses information technologies and algorithms to improve the efficiency of livestock farming (Berkmans, 2016). In extensive farms, the issue is mainly to manage better diversity and variability, for heterogeneous animal groups operating in large, diverse areas of rangeland (Bocquier *et al.,* 2016). While in intensive farms, precision livestock farming enables to replace the farmer by automated devices for a number of operations, this is not possible/advisable in agro-pastoral systems, due to the complexity of the environment and to the multiple functions associated with natural and semi-natural grasslands (Bocquier and Jouven, 2016). Current research for grassland-based farming focuses on the development of virtual fences to facilitate the control of free-ranging livestock without shepherding or physical barriers, or the use of unmanned aerial vehicles combined with a variety of animal-born sensors to determine their location and health status.

In MSRS, technological packages mainly aim at providing farmers with information enabling them to gain a better understanding of the system and thus implementing an adequate adaptive management. Recently, the CLOchèTE project (http://idele.fr/reseaux-et-partenariats/clochete.html) studied the possible applications of GPS and accelerometer technologies to assist French pastoral farmer in their grazing management and shepherding activity. Based on individual interviews and focus groups with farmers, 4 main applications were identified (Guinamard *et al*., 2018): (1) Real-time localisation of flocks grazing free in large areas of natural grasslands, or in case of flock splitting; (2) alert on the farmer's cell phone if the flock crosses certain geographical limits, or in case of panic movements possibly related with predation; (3) knowledge of animal grazing circuits; (4) monitoring of animal activities in time and space. The last two applications were mentioned mainly by farmers who did not practice shepherding. Both for those farmers and for the shepherds who change often flock and place, such information would be very useful to build or update LEK about flock behaviour. Another means by which to improve LEK is sharing it and discussing it with peers. The Pastoral Rummy (Zapata *et al.,* 2017) is a serious game based on a physical board and cards, and on a computer simulator; groups of farmers or students design pastoral systems on the board, and discuss the performance of the system based on simulation results. Again, technologies make it possible to produce quantitative information, difficult to access directly, but very useful to understand the functioning of pastoral systems.

The diversity of pastoral situations and the difficulty to measure the state of the system in heterogeneous conditions and large surface areas, limit the amount of scientific knowledge on the subject. In the future, the deployment of sensors (even as simple as embarked GPS) in pastoral farms will produce large amounts of data. Gathering such data and analysing large, heterogeneous datasets would boost research about the ecological functioning and the management of pastoral systems.

3. Reconnecting livestock farming to other activities in a "land-sharing" perspective

The last century has been characterized by urbanization and desertification of pastoral areas, mostly human desertification in Southern Europe and ecological desertification in Northern Africa (Ait-Alhayane, 2016). Industrialization created a gap between urban and rural areas. In rural areas, the specialization of farms and sometimes of whole geographical regions encouraged a spatial separation between agricultural and livestock activities. In the 1990s, the development of agri-environmental measures in the CAP introduced in Europe the idea of multiple functions associated with agriculture, and especially with extensive livestock farming. More recently, long lists of ecosystem services provided by livestock farming systems have been identified (Ryschawy *et al*., 2015), although only a few are paid to the farmers through agri-environmental schemes, diversification of activities or higher prices for agricultural products.

Mediterranean pastoral areas are associated with biodiversity conservation issues, traditional products, cultural landscapes and tourism. In Europe, the LIFE programme counted among its objectives to establish the best farming practices to maintain or enhance the natural value of Natura 2000 sites and generate examples of success stories, in order to provide a sound basis for policy making (Silva *et al.,* 2008). A couple of recent examples are: (1) the LIFE Montserrat project (https://lifemontserrat.eu/en/) that aimed at achieving biodiversity conservation and forest fire prevention through integrated silvopastoral management and (2) the LIFE+ Mil'Ouv project (http://idele.fr/reseaux-et-partenariats/life-milouv.html), aimed at improving the utilization of agro-pastoral habitats through the dissemination of skills, information, methods and relevant advice to the various stakeholders. In a number of rural areas, farming activities coexist with different forms of nature-related tourism. Although there may be some trade-offs (namely, competition for land and labour) many synergies among both sectors can be exploited. Value chains can be developed for farm products which incoming tourists associate with a particular area and production system (Renting *et al.*, 2003; Aubron *et al*., 2014). On the other hand, touristic activities can benefit from the existence of farms in a given area (Van Huylenbroeck *et al.*, 2006) or directly from livestock grazing, such as ski stations located on alpine grasslands where livestock grazing in the summer ensures the stability of the snowpack in the winter (Casasús *et al*., 2014).

The recent awareness of the negative impacts of input-based agriculture and the opportunities offered by agroecology have encouraged stakeholders to re-associate livestock farming to perennial cropping, silviculture, or even areas devoted to recreation or energy production. Such associations usually imply combining livestock periodical grazing with other utilizations of the resources available on the land. Wooded areas are re-considered and identified as potential providers of bedding (from wood), forage trees and fruit used as concentrate for livestock (see: AGROSYL project, http://idele.fr/no_cache/recherche/publication/idelesolr/recommends/presentation-du-projet-agrosyl.html). The limitations in terms of herbicide use in vineyards and orchards encourage farmers to resort to livestock grazing to keep the herbaceous layer short and thus control the competition for water with permanent crops. Such practice is also beneficial to livestock farming, since it provides alternative and complementary forage resources (Napoleone *et al.,* 2019). Non-agricultural stakeholders such as municipalities or photovoltaic park operators increasingly envisage to resort to grazing to manage the grasslands within their responsibility; this practice, known as "eco-pasture", is rapidly developing (Delfosse *et al*., 2016). Such promising options in terms of land sharing in the Mediterranean basin require mutual understanding from the stakeholders involved, the adaptation of their individual practices and a favorable legal framework. Specific tools can also be developed, for example to support targeted grazing (Nobrega *et al*., 2017).

V – Conclusion

Grassland-based MSRS benefit from a positive image, a specific quality of the animal products and – if an appropriate grazing management is implemented – of a positive environmental footprint. Technical options to increase the contribution of grasslands to MSRS exist, but they need to be associated with social and technological developments, since they cannot solve all the problems. The challenges which Mediterranean grassland-based systems have to face are summarized in table 1, together with their consequences, the potential solutions to secure farm sustainability discussed in this paper and the research and development perspectives identified by the authors. Such research perspectives imply leading interdisciplinary projects, which connect plant and animal sciences (to "optimize animal production at pasture"), agronomic (*s.l.*) sciences and information technologies (to "produce IT-based tools") or, more often, agronomic (*s.l.*) and social sciences, possibly in the framework of participatory research. Various projects have already started tackling these questions. Further research is needed to investigate the diversity of existing situations (in terms of seasons, physical environment, social context, type of system, …), but also to find, among such diversity, the common features that can be used as a basis to design efficient agroecosystems, product differentiations, grassland-oriented agricultural policies and development schemes.

Table 1. Grassland-based livestock farming systems (LFS) in Mediterranean areas: from global/local challenges to research and development perspectives

Challenges	Climate change	Market trends	Agricultural policies	Social trends
Drivers of change	• ↘ Forage production • ↗ Unpredictability	• ↗ Quality standards • ↗ (S) or ↘ (N) in quantitative demand	• ↗ Environmental concern but poor recognition of ES	• ↘ Attractiveness of the job (farmer, shepherd) • Changes in access to land
Impact on (silvo)pastoral LFS	• ↘ Self sufficiency • ↗ Intensification	• Difficult to fit main standards	• Policies *de facto* unfavourable to extensive grazing	• Lack of generational turnover • Complex grazing management
Potential solutions	• Plant mixtures and cultivars adapted to local conditions • Diversification of grazing areas	• Differentiate the products from (silvo)pastoral LFS • Direct sale of products	• Pay for the ES provided by grassland-based LFS • Take into account the peculiarities of silvopastoral LFS	• Collective management of large pastoral areas • Improve working conditions
Research and development perspectives	• Produce the seeds locally • Optimize animal production at pasture	• Reconnect farmers and consumers • Connect LFS and other activities	• Quantify the ES provided • Objectivize the specific features of silvopastoral LFS	• Produce IT-based tools to facilitate LEK-building and grazing management.

S: south Mediterranean countries / N: Nord Mediterranean countries / ES: Escosystem Services / LEK: local ecological knowledge.

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Management and restoration of pastures and rangelands in the Mediterranean basin from the Northern and the Southern perspective

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Abstract. Pastoralism is a traditional land use in the Mediterranean region lasting for several thousands of years, where vegetation and animal communities are adapted to deal with summer drought periods and grazing pressure. There is a difference between the two shores of the Mediterranean in terms of pastoralism, it is more a mode of subsistence in the South, whereas in the North is a complementary activity each time less profitable. In addition, there is a clear North-South climatic gradient that determines rangelands productivity, carrying capacity, sustainable management and resilience. The environmental and socio-economical differences among the Northern and the Southern shores of the basin determine separated trends in both shores, leading to different management and future perspectives of rangelands. In addition to climate, differences in demographic pressure and socio-economical context influence rangeland status across the Mediterranean basin. Abandonment of grazing activities in North Mediterranean region vs. grazing intensification or even sedentarization in South Mediterranean region are the main socio-economical drivers, with important consequences on rangeland conservation. Despite regional differences, global warming affects the Mediterranean rangelands as a whole, increasing the shortage of water availability and the summer stress. These common perspective should promote that northern and southern rangeland managers and researchers learn from each other to deal with rangeland conservation, management and restoration. The latest research address pastoral production systems as a whole, and considers pastoral improvement techniques as a component in a holistic approach.

Keywords. Mediterranean rangelands – Productivity – Land abandonment – Overgrazing – Climate change.

Gestion et restauration des pâturages et des parcours dans le bassin méditerranéen du point de vue du Nord et du Sud

Résumé. *Le pastoralisme est une forme d´utilisation traditionnelle des terres dans la région méditerranéenne depuis plusieurs milliers d'années, où la végétation et les communautés animales sont adaptées pour faire face aux périodes de sécheresse estivale et à la pression du pâturage. Il existe une différence entre les deux rives de la Méditerranée en termes de pastoralisme : il s'agit davantage d'un mode de subsistance au Sud, alors qu'au Nord c'est une activité complémentaire chaque fois moins rentable. En outre, il existe un gradient climatique Nord-Sud très net qui détermine la productivité, la capacité de charge, la gestion durable et la résilience des parcours. Les différences environnementales et socio-économiques entre les rives nord et sud du bassin déterminent des tendances distinctes sur les deux rives, ce qui entraîne une gestion différente et des perspectives d'avenir différentes pour les parcours. Outre le climat, les différences de pression démographique et de contexte socio-économique influencent l'état des parcours dans le bassin méditerranéen. L'abandon des activités de pâturage dans la région nord-méditerranéenne et, au contraite, l'intensification du pâturage ou même la sédentarisation dans la région sud-méditerranéenne sont les principaux facteurs socio-économiques, avec des conséquences importantes sur la conservation des parcours. Malgré les différences régionales, le réchauffement climatique affecte les parcours méditerranéens dans leur ensemble, en augmentant la pénurie d'eau disponible et le stress estival. Ces perspectives communes devraient inciter les gestionnaires et les chercheurs du nord et du sud à apprendre les uns des autres en matière de conservation, de gestion et de restauration des terres de parcours. Les dernières recherches abordent les systèmes de production pastorale dans leur ensemble et considèrent les techniques d'amélioration pastorale comme une composante d'une approche holistique.*

Mots-clés. *Parcours méditerranéennes – Productivité – Abandon des terres – Surpâturage – Changement climatique.*

I – Introduction

Grazing land ecosystems occupy approximately one third of the earth's land area (MEA, 2005; Gibson 2009, Delgado *et al*., 2011; Sayre *et al.,* 2013) and support about 50% of the world's livestock and wildlife (Niamir-Fuller 1999, Allen *et al.,* 2011). At least 1 billion rural and urban people depend on these ecosystems for their livelihoods, often through livestock production, or for ecosystem services that affect human well-being (Ragab and Prudhomme, 2002). Extensive grazing on rangelands for livestock production represents the key food production and livelihood system in the world's drylands. Pastoralism is recognized as one of the most important agricultural systems with high natural value in Europe (European Council Regulation (EC) 1698/2005). In the Maghreb, a population of 12 à 15 million lives in harsh environment regions (steppes, mountains, arid areas) where dominate agro-pastoral systems based on the use of rangelands (PASTRES, 2018). Pastoralism continues to be an important source of livelihood in the Maghreb; share of livestock in agricultural GDP ranges from 26 percent in Morocco to 70 percent in Mauritania (PASTRES, 2018).

Ruminants and associated grazing lands provide a number of important benefits for humans and the environment (Teague *et al*., 2016). Provision of these ecosystem services is dependent on appropriate management (Teague and Barnes 2017), while unsuitable management practices have caused an overall decline in historic ecosystem services generated through the grazer/grassland relationships (Hillenbrand *et al*., 2019). Nearly all pastoral cultures are facing great difficulties (Weber and Horst, 2011) because rangelands are degrading worldwide, primarily due to inappropriate land use practices, among other reasons (Delgado *et al*., 2011), especially in arid and semi-arid rangelands (Schacht and Reece, 2008). For instance, on most of the world's grazing lands, continuous or relatively unmanaged grazing in excess of carrying capacity has resulted in degraded vegetation and soils (Teague *et al.,* 2011), declines in productivity and biodiversity, and a reduction in ecosystem resilience (Frank *et al.,* 1998).

Mediterranean climate has distinctive traits shared all around the basin, which are a summer water deficit and growths periods in spring and autumm. This fact determines a yearly heterogeneous management driven by the the seasonal plant productivity (Perevolotsky and Seligman, 1998). Besides this common feature of the whole basin, in the Mediterranean region there are strong spatial gradients, mainly a North-South gradient in rainfall and temperatures, reflected at the end in a strong and clear aridity gradient (Bolle, 2012). This aridity gradient ranges from humid at some regions of the North Mediterranean shore to hyperarid in the driest regions of the south Mediterranenan region, with all the conditions in between these two extremes. Aridity strongly determines rangeland productivity, management and degradation processes. In this sense, plant communities that support the Mediterranean rangelans are highly diverse, with vegetation ranging from closed forest (i.e. Pinus sp., Quercus), shrublands and grasslands.

Climate change is one of the most challenging environmental issues in the whole Mediterranean region. Climate is expected to become warmer and drier in many regions of the world, and these trends are predicted to be strong and fast in the Mediterranean region (Cramer *et al*., 2018). Climate change is going to increase aridity in the Mediterranean region, which will impact Mediterranean rangeland productivity and diversity, and ultimately can impact people well-being and rural life. Climate change could be the direct cause of desertification (irreversible ecosystem degradation) in many Mediterranean areas (UNCCD, 1994). The consequences of combined effects of climate change and overgrazing can be worse in the South Mediterranean rangelands, but desertification risk is also high in the West and East Mediterranean regions (Alados *et al.,* 2007; Kouba *et al.,* 2018; Rubio *et al*., 2009).

Ecological research on grazing systems can help preventing and mitigating desertification in the Mediterranean ecosystems. Firstly, the understanding of the processes and functioning of the grazing systems from the ecosystem perspective can help preventing irreversible degradation. From an ecological point of view, Mediterranean grazing systems are ecosystems, whose structure and

dynamics are influenced by processes and factor that occur at a wide range of spatial and temporal scales. Structure and functioning of rangelands are maintained by ecological processes that occur at individual scale, such as seed dispersal, biotic interactions and plant growth and persistence. From the landscape level there are factors and processes that also affect grazing systems, such as climate and other abiotic factors, the type of grazing management and land fragmentation among others (Alados *et al.,* 2014; Gartzia *et al.,* 2016a). Looking at grazing systems as ecosystems, we can identify relevant ecological parameters, of ecosystem components, to control in order to evaluate the effect of grazing on vegetation, such as productivity, species diversity and plant height (Perevolotsky & Seligman, 1998). Both productivity and diversity are usually maximum at intermediate grazing pressure (Escos 1997; Alados *et al.,* 2003).

On the other hand, technics based on ecological restoration can help mitigating desertification once has occurred. In the ecological restoration the target ecosystem should reach similar species composition and structure, biotic fluxes, self-sustainability and resilience. Nevertheless, in order to evaluate the success of restoration efforts, both biophysical and social-economical indicators should be taken into account. (Bautista *et al*., 2010; Cortina *et al.,* 2011).

The objective of this paper is to briefly address and discuss the different approaches for management and restauration of pasturelands and rangelands and review the latest advances on the management and restauration of pasturelands and rangelands across Mediterranean conditions.

II – The Northern shore perspective

The North Mediterranean region is a complex mosaic of diverse landscapes ranging from humid to semiarid climatic conditions. The environmental value of extensive grazing systems is officially recognized and many of them are included among the High Nature Value (HNV) farmlands by the UE (EEA, 2012). The concept « HNV faming » is a recognition of the role of traditional low-intensity farming systems for biodiversity conservation in Europe. Environmental conservation and the protection of natural heritage are developed in different laws that provide for the conservation, sustainable use, restoration and enhancement of the grasslands. The ecosystem services provided by extensive grazing systems in the North Mediterranean countries are diverse and well-recognized (i.e. forage production, open landscapes that prevent fires, save habitats for wildlife, ensure biodiversity, aesthetic values for tourism, cultural life, rural vitality....).

During traditional pre-modern period (previous to 1970) social capital of rangeland ecosystems were dominated by extensive grazing and traditional non intensive agriculture. With the Common Agricultural Policy (CAP) regulations the rural activities in the north Mediterranean countries changed in the traditional pasture management and breeder involved. For example, while traditionally sheep has been predominant in Central Pyrenees Mountains, after the CAP subventions, there has been a transition from sheep to cattle with important implications on the pasture dynamics. This has several consequences for the management of pastures, whose preliminary results do not bring good news. The overgrazing by cattle on the “best pastures” and the absence of cattle in other areas can bring fatal consequences with the loss of high valuable grasslands. In other areas as in Asteroussia Mountains, subsidies favored the implementation of husbandry activity, increasing overgrazing (Alados *et al.,* 2014; Gartzia *et al.,* 2016a, 2016b).

The socio-economic development that has taken place in the period 1991-2011 in southern European countries has given rise to an increase of leisure and tourism activities. An important tourism development related to two different models of tourism in mountain ecosystems are: ski resort or sport tourism and nature tourism, based on singularity, biodiversity and landscape quality. An important factor in the implementation of CAP aids has been the Measure of “unique payment” referring to all CAP subsidies. The direct aid for agrarian rents in the first pillar of the CAP (direct payments) and the second pillar of the CAP are Rural Development Program.

Extensive grazing systems of North Mediterranean region are threatened by socio-economical trends in European countries, including a clear tendency to rural life abandonment in the last decades (Morand, 1983; Fernandez *et al.,* 2017; Alados 2014). In addition, polices and regulations concerning the conservation of rangeland ecosystem lead to the prohibition of traditional management practices as fire and clear cutting to control shrub colonization into the grasslands. As a consequence of this trend a landscape transition has been identified as the key threat to ecosystem services and human well-being since the second half of 20th century (MEA 2005). In grazing systems, the most important land cover transition is the grassland-woodland transition that took place in many European countries after the mid-20th Century. These changes had important implications in the provision of ecosystems services on which human societies depend. Grassland-Woodland transition appears to result from a number of distinct factors and their interactions including grazing pressure and management, anthropogenic disturbances or from long-term climate change. In addition, as a consequence of this trend, an heterogeneous use of the pastures and rangelands is common. While the most accessible resources are intensively used, there is a massive abandonment of the most inaccessible grazing lands (Gartzia *et al.,* 2016). Large scale grazing systems are being massively abandoned (Caballero *et al.,* 2009; Alados *et al.,* 2014) while forage supplements are increasingly included in the grazing management instead.

Both climate change and social-economical trends are the main challenges for the conservation of pastures and rangelands in the North Mediterranean countries, often in an interactive and synergistic way (Gartzia *et al.,* 2016a). The nature of the degradation process depends on the type of rangeland. In semi-arid rangelands the degradation process is related to desertification, and both climate change or an inappropiate use of the resources are involved (Baindbridge, 2007). On the other extreme, in humid pastures, the land abandonment leads to the loss of the pastures by shrub encroachment, often exacerbated by climate warming (Komac *et al.,* 2013; Gartzia *et al.,* 2014). Both degradation processes are irreversible without human intervention, requiring active restoration to revert. However, restoration technics at these two extremes of the grazing land degradation are different.

1. Reverting shrub encroachment

During the last decades, the abandonment of traditional land use practices are largely contributing to the colonization of unpalatable woody species in grasslands, what is called as shrub encroachment. This is a common trend in Europe, and especially in the European Mediterranean area, there is a massive process of revegetation of grazing lands (Gartzia *et al.,* 2014, 2016a). Shrub encroachment causes irreversible changes in ecosystem functioning. Once the pastures are colonized by shrubs, the new conditions are very difficultt to revert. Land managers employ different restoration technics to reverse plant succession, such as burning or clear-cutting. Ongoing long-term ecological studies in the Pyrenees are giving light on to the best way to control and revert shrub encroachment (Komac *et al.,* 2013; Nuche *et al.,* 2018; Alados *et al.,* 2019). After several years following trends in soil and plant community properties after different treatments (shrub burning vs clear-cut; Figure 1) results point towards different conclusions based on the shrub species involved. In general, in the case of the pyrophite dominant shrub *Echinospartum horridum*, clear-cut is the best strategy always followed by high grazing pressure to control the *E. horridum* germination. In the case of species able to regrowth after cutting, such as *Rosa*. sp. burning is better strategy because those species live at low altitude close to forest, the use of burning is not advised, Consequently the only option possible is clear-cut with heavy grazing in humid habitat as Pyrenees. In ecosystems with a long evolutionary history of grazing vegetation is adapted to large herbivores and consequently, livestock grazing is necessary to maintain ecosystem biodiversity. Grasslands-grazers positive feedback is based in one hand in the capacity of grasses to re-growth from intercalary meristems located at the base of the defoliated shoot and the news steam that develop at the ground surface, and the increases of nutrients contents of that young plant tissue, resulting in the favorable effect of grazers on grassland biomass and nutrient concentration.

Fig. 1. Burning (left) and clear-cut (right) treatments to control *Echinospartum horridum* expansion in Pyrenean pastures.

2. Restoring desertified rangelands

Semi-arid rangelands productivity and functioning are controlled by strong plant-soil feedbacks (Rietkerk and van de Koppel, 1997). Vegetation cover enhance soil water infiltration and fertility, which in turn benefit plant establishment and productivity. Overgrazing causes negative effects on these systems though the loss of vegetation cover and the bare soil compaction, that hamper soil conservation (i.e. decrease water infiltration, increase erosion processes and salinization) and plant establishment, leading to an irreversible degradation of the rangeland (Baindbridge, 2007). This degraded state is highly stable and persistent, and it is characterized by low vegetation cover, low diversity and poor forage quality (Suding and Hobbs, 2009; Figure 2). To restore previous preserved conditions is challenging, as soil conditions are not suitable any more for seedling establishment. Traditional restoration of these areas includes abiotic amelioration and soil conditions improvement through ploughing the soil to increase infiltration or creating small dams to prevent run-off and erosion. However, these techniques are often expensive and quite invasive (Papanastasis, 2009). Positive biotic interactions among plants (i.e. facilitation) are well known in arid and semiarid ecosystems to be a relevant ecological mechanism that increases plant establishment and sustain diversity and productivity (Callaway 2007). Facilitation of species of interest by « nurse plants » has been successfully applied in semi-arid Mediterranean rangelands (Pueyo *et al.,* 2009; Padilla, 2006). More research on this low-cost restoration treatment is necessary, as pioneer results are promising.

Fig. 2. Well-preserved semi-arid grassland dominated by *Lygeum spartum* (left) and eroded and salinized land (right). Both in the Middle Ebro Valley (Spain).

III – The Southern shore perspective

The vast majority of pastoral systems in Africa, changed during the 20th century. The trends and perturbations faced by pastoralists across the world include drying of the environment due to recurrent droughts, population increase, agricultural encroachment, preferential subsidies and policies supporting crop cultivation, lack of government support for transhumance, breakdown of the traditional, local institutions and systems for managing natural resources, inappropriate development approaches, sedentarization and concentration of livestock and the growing economic vulnerability of pastoralists (Niamir-Fuller 1999).

A brief history of the development policies undertaken in the Southern shore will provide the succession approaches and the lesson learned (Figure 3).

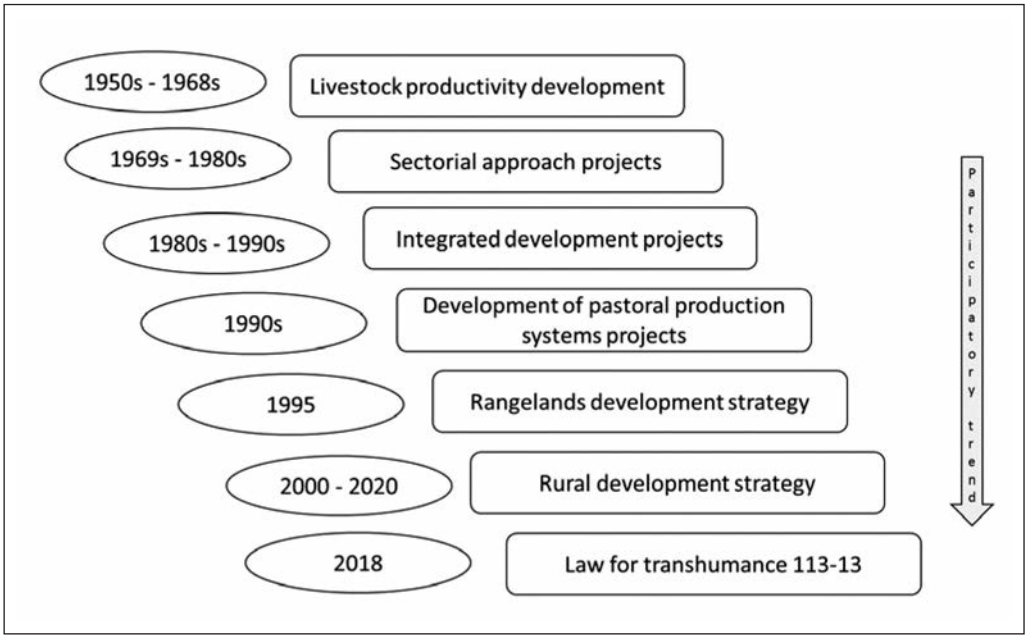

Fig. 3. Different approaches to pastoral development in Morocco.

Under the colonial era, the focus was on the livestock development rather than on the enhancement of the livelihoods (Niamir-Fuller 2019). After their independence, the state's interventions on rangeland were limited to health prevention campaigns against diseases with economic impacts. With the recurrent droughts and their negative impacts on livestock, the governments established strategies such as Livestock Safeguard Fund to provide support to livestock farmers, in the form of a livestock feed subsidy, and to cover transportation costs. During the period 1970s to the early 1980s, pastoral policy meant more classical approach based on pastoral improvement actions carried out in defined areas, i.e. Pastoral Improvement Areas (PAPs) in Morocco with no success. In Tunisia, the government linked the problems of rangelands with collective land tenure and implemented a law in 1971 to start of the privatization of collective lands that reduced drastically the area of rangelands (Ben Sâad and Bourbouze, 2010). As consequence of the reduction of rangelands area, there was an increase in the grazing pressure which resulted in large degradation of the remaining rangelands (Zaafouri, 1998). Between 1971 and 1997, one million hectares of good rangelands were cropped, mainly in arboriculture and cereals.

The following phase (1980s – 1990s) was the Integrated Development Projects (IDP). The aim was to associate the livestock producers and to correct the significant imbalance that existed between rain fed areas and irrigated areas. The results obtained did not live up to the expectations and the investments made. The Middle Atlas Central project in Morocco funded by World Bank was an example of IDP with a negligible impact.

The third phase that emerged in the early 1990s addressed the pastoral development in more holistic approach and take advantage from Lessons from the succession of policies. These projects are more participative and not top-down approaches, involved all stakeholders and use the pastoral cultural heritage to manage rangelands.

The threats to pastoral systems sustainability in the South shore of the Mediterranean are:

A. The overexploitation of resources and the desertification

In the South of the Mediterranean, plant communities have been under high grazing pressure for long time. Usually overgrazing had been associated to uprooting shrubs such as *Artemisia herba alba* which increase the risk of desertification (Figure 4) and made those good plant communities crossing threshold to irreversible state (Standish *et al.,* 2014).

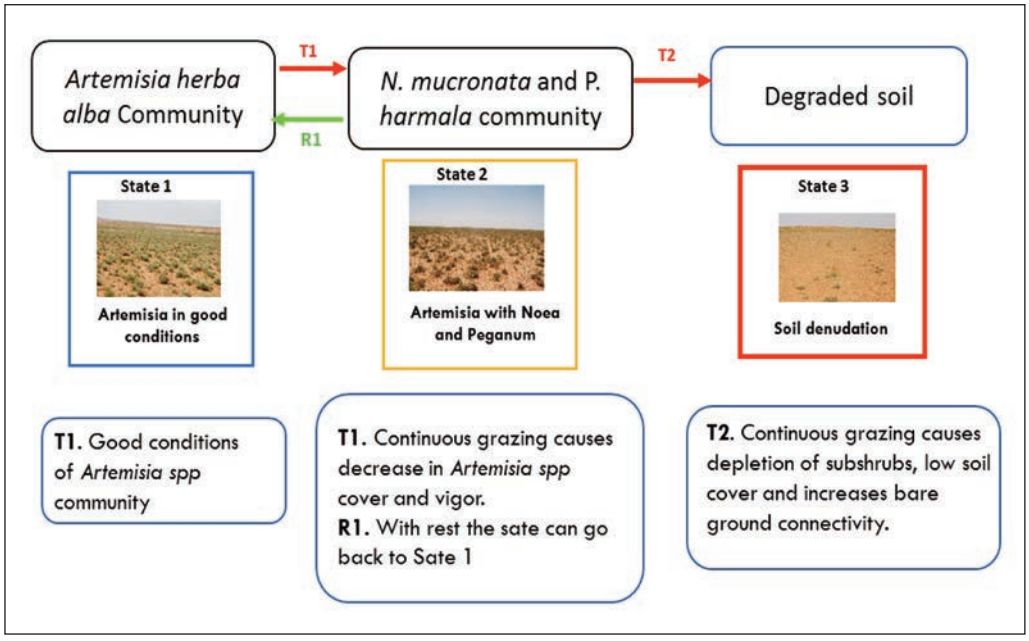

Fig. 4. Alternative States in the *Artemisia herba-alba* community as responses to the overgrazing (adapted from Bestelmeyer *et al.,* 2015).

B. The threats of climate change

The Mediterranean is the second most exposed region in the world to climate change, with 25% rainfall reduction projected along its southern rim in forthcoming decade (Ouled Belgacem and Louhaichi 2013). All climate projection scenarios indicate that North Africa region will be exposed to three key climate change hazards: (i) long-term climatic desiccation; (ii) increased weather/climate variability, extremes and uncertainty; and (iii) rising temperature. Adaptation of rangeland

species will differ: Xerophilous species will stand higher temperatures, for instance, i.e., climate change seems to favor *Haloxylon* spp (Ouled Belgacem and Louhaichi 2013). In traditionally managed grazing systems, mobile pastoralism provides a way to respond to variations in intra– and inter-annual climatic fluctuations (Fryxell and Sinclair 1988) and prevent desertification by overgrazing (Homann *et al.,* 2008). Mobility of herds and people, i.e. transhumance /transterminance, allows a better exploitation of rangelands. Periods of resting helps to mitigate the effects of overgrazing and warming, restoring productive capacity, and mitigating erosion and desertification.

Recently, researchers have shown that livestock have little impact on forage resources (Sullivan and Rohde 2002; Lind *et al.,* 2003) and so are not considered the main cause of degradation of rangeland and consequently desertification (Okayasu *et al.,* 2010). This is explained because high levels of climatic variability with peak droughts cause crashes in the animal populations, causing higher mortality rates in livestock and as a result overgrazing is halted before the desertification process is triggered (Derry and Boone 2010). This is only the case when animals are not provided with supplementary food during periods of food shortage.

C. The absence of defined policy to sustain pastoral systems

In the southern shore of the Mediterranean, there are no national policies to help pastoralists outside of the drought safeguarding plans. To cope with this, pastoralists are now trying to ensure the sustainability of their system through the use of the livestock/agriculture association in dry or irrigated by pumping deep water wells in addition to non-agricultural income from emigration, trade or other small jobs. In the steppe regions, most of the small livestock holders switched to other small jobs in other sectors rather than raising sheep and goats. It is certain that pastoralism can provide more global environmental benefits with greater attention to domestic markets where fewer trade barriers exist. Extensive low-input farming where livestock are fed on rangelands is certainly an organic system and niche markets could provide an important marketing option in the future. It should be noted that in most developed countries, the supply of organic meat cannot meet consumer demand which justify the need to promote such products from rangelands.

Finally, an important issue to address in the south is the change of the policy framework dealing with the land tenure in order to control animal numbers for the adjustment of the grazing pressure. In the meantime, a special consideration should be done to the pastoral cultural heritage that had ensured for centuries the ecological integrity of the pastoral ecosystems.

1. Latest advances on the management and restauration of rangelands in the Southern shore the Mediterranean basin

The latest advances on the management and restauration of rangelands address pastoral production systems in their entirety and considers pastoral improvement techniques as a simple component of an approach to pastoral development.

A. The revival of transhumance to conserve biodiversity

The approach is built on the premise of “the revival of transhumance to conserve biodiversity” through the creation of pastoral associations in charge of the management of displacements and the development of routes (defenses, water points, etc.), but also on training (“capacity building”). Mobile pastoralism strengthens rangeland biodiversity, rangeland carbon stocks and supports the conservation of rangeland habitats. In pastoral systems in semi-arid areas of Spain sheep transhumance on traditional migratory corridors has been found to support habitat connectivity and biodiversity through the transport of seeds and insects by sheep (Manzano and Casas, 2010). In the Ouarzazate areas, associations of transhumers aim to maintain the transhumance between the win-

ter pastures of the steppe and the grasslands of the High Atlas (Akasbi *et al.,* 2012). The management of the transhumance should be done according to the Law 113-13 relative to the regulation of the transhumance. Corridors are to be identified, delineated, mapped and equipped to facilitate mobility of herds and people. The regulation of transhumance is not new. In Spain, livestock mobility was promoted by an Act of Parliament passed in 1995 that legitimized the pastoral use of 120,000 kilometers of transhumance corridors in the country.

B. The creation of pastoral cooperatives

The implementation of the pastoral cultural heritage to manage rangeland resources is another issue that is undertaken through the creation of pastoral cooperatives (Mahdi 2009). Among these projects, the Oriental Range and Livestock Development Project (PDPEO) is a large-scale operation initiated in the early 1990s by the Moroccan State, to improve the state of the rangelands, the conditions of the breeding and the populations income of Eastern Morocco. To achieve its objectives, the project has developed an innovative approach to raise the awareness of pastoralists to the problems of degradation of rangelands and to involve them in the process of planning, carrying out and monitoring pastoral improvement actions, through 34 pastoral cooperatives formed on the basis of the "ethno-lineage" principle. The main rangeland improvement techniques used by the pastoral cooperatives are rest of grazing areas for more than three years and fodder shrubs plantations. During the life of the projects, 62% of the grazing area for rest planned was achieved (Table 1).

Table 1. Areas respected for rests for the 34 pastoral cooperatives

Pastures put to rest (in ha)	Béni Guil	Tendrara et Maâtarka	Total
Scheduled	114 000	204 000	318 000
Realized	75 800	122 000	197 800
Completion rate (in%)	66	60	62

In addition to the rangeland restoration done by pastoral cooperatives, the were interlocutors to the administration for rangeland development. Pastoral cooperatives ensure the sustainability of pastoral improvement actions and take care of the pastoral infrastructure and equipment management.

IV – Common perspectives. Holistic management and related regenerative practices

According to Hillenbrand *et al.,* (2019), agricultural production should be guided by regenerative management protocols that enhance soil and ecosystem function to improve long-term sustainability, including ecological, economic and social resilience. In this sense, land should be stewarded to enhance its potential for self-regeneration (MEA 2005) through practices that maintain or restore soil and ecosystem function and resilience that is required for sustainable use in the long term (Teague *et al*., 2013).

Some form of grazing management is usually required to maintain pastures in a desirable composition and productive state (Kemp and Dowling, 2000). However, the appropriate intensity and management of grazing is still debated (McCosker 2000). Grazing managers and scientists have tried various forms of grazing management systems, varying from continuous through an abundance of rotational practices. However, conventional systems (e.g. continuous grazing) have been suggested as decreasing biodiversity (Alfaro-Argüello *et al*., 2010) and, when widespread practiced at high stocking rates, inducing long-term land degradation (e.g., Teague *et al*., 2013; Savory and Butterfield, 2016). Although other simple forms of grazing management (e.g. rotational grazing) have been recommended for over a century as an important tool to sustain grazing land productivity and im-

prove animal management, they have often been applied rigidly rather than adaptively, and with mixed results (Teague and Barnes 2017). In general, conventional systems have been designed without taking into account the full complexity of agro-ecosystems. To effectively address complex adaptive ecosystems such as Mediterranean grazing lands are, requires a planning process that embraces complexity, rather than a pre-determined management system designed for simplicity (Savory 1999; Teague *et al.,* 2013).

Particularly promising strategies to effectively address complexity of grazing lands are adaptive grazing decision-making practices called Holistic Management (HM) developed by Allan Savory (Savory 1999) and HM closely associated grazing systems, such as adaptive multi-paddock grazing management (AMPG), intensive rotational grazing (IRG), cell grazing (CG) or high-density-short duration grazing system (HDG). All these systems have in common a systemic view, a regenerative approach for grazing lands, and they focus on better managing the spatio-temporal aspects of grazing. Sound financial planning, as well as the socio-cultural aspects within which it is integrally tied, are also addressed from HM and derived strategies (Savory, 1999; Weber and Horst, 2011; Briske *et al*., 2014; Savory and Butterfly, 2016; Teague, 2018).

Holistic Management is an adaptive and highly flexible practice. It represents a decision-making framework that emphasizes the interdependence of environmental, economic, and social wellbeing. Under HM, decisions are made by focusing upon the relationships among resources (including land, wild and managed biodiversity, water, soil and other resources), people, and financial outcomes (Savory, 1999). HM focus not only on livestock and grasslands, but it takes also into account the whole ecosystem function to be maintained, wildlife needs, planning for facing drought, fire threats, cultural needs, regenerative approach for grazing lands, restoration of soil health and water infiltration and retention and it encompasses far more than systematic pasture rotations (Weber and Horst, 2011). It is becoming increasingly clear that the key to sustainable use and recovery from degradation involves grazing for short periods, concentrate livestock at relatively high densities rather than continuous grazing, planning recovery and adjusting stock numbers to match forage biomass (Teague *et al*., 2013; Jakoby *et al*., 2015; Savory and Butterfly, 2016; Wang *et al*., 2016; Peel and Stalmans 2018). Moreover, HM often involves cessation or reduction in chemical fertilizer use, an emphasis on native pastures instead of exotic or annual pastures, grazing rather than fire as a way of recycling soil nutrients, and monitoring pastures in order to anticipating feed availability, e.g. under periods of drought (Sherren *et al*., 2012).

Many studies have shown positive effects of HM and related practices across numerous studies in several continents (mainly in Africa, America and Australia), climates (from arid and semi-arid to mesic and humid) and ruminant species (cattle, sheep, goats, bison). While some studies have been performed under Mediterranean climate (https://holisticmanagement.org/), more regional studies are needed. There is a high variability in results and success reported, that may be due to different climates, soil and vegetation types, approaches and scales used (i.e., real commercial farms complex landscapes long term studies versus controlled limited-scale short term experimental studies), the use of similar –but not identical– types of management and disciplines (Briske *et al*., 2014, Sherren and Kent, 2017; Teague and Barnes, 2017). Sherren and Kent (2017) suggested that an integrative work that combines social science and management, environmental scholars and experimental scientists is necessary to overcome the existing polarization in the literature.

The HM approach might be better suited to the North of the Mediterranean where there is no pressure on rangelands caused by the demographic increase and where land tenure is not the main constraint for grazing lands restauration. In the southern shore of the Mediterranean, most pastures used by traditional pastoralists are collectively owned while the livestock herd is privately owned. This opposition between the collective ownership of the grazing resources and the individual ownership of the livestock put no incentive to control animal numbers and duration of grazing which results in high damage of vulnerable range vegetation. The HM approach is certainly not appropriate for collec-

tive rangelands owned by heterogeneous ethnical group where there is no control on livestock numbers and where livestock is used for different purposes rather than just production as it is the North.

We suggest that future research should address Mediterranean pastures, rangelands and related pastoral systems through a holistic approach framework, taking into account the whole agroecosystem with all its components and interactions, developing key indicators related to ecosystem functions as well as to production and socio-economic aspects of the farms management and conducting trials at appropriate spatial and temporal scales in realistic contexts in collaboration with all stakeholders.

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Extending forage production using mixtures in a Mediterranean rainfed environment

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Abstract. Forage mixtures based on perennial grasses and legumes have a considerable interest for farmers in Mediterranean rainfed livestock systems, in order to extend the grazing season and establish temporary grasslands. Currently, in South European rainfed farming systems based on annual forage crops, some gaps in forage availability are experienced during early autumn and late spring. With the aim to assess dry matter production and forage availability along seasons and years, forage mixtures based on lucerne and perennial grasses (tall fescue and cocksfoot) were tested for three years in an experimental field in Sassari (Italy). The erect type of lucerne, both in pure stands and in binary mixtures, showed the highest productions among treatments (up to 12 t of dry matter per year). It also had the best seasonal forage distribution, being able to grow during the summer in rainfed conditions and during winters characterised by mild temperatures.

Keywords. Perennial legume-grass mixtures – Lucerne – Tall fescue – Cocksfoot – Forage yield – Drought tolerance.

Étendre la production fourragère avec des mélanges légumineuses-graminées en conditions pluviales méditerranéennes

Résumé. *Les mélanges fourragers à base de graminées et de légumineuses pérennes ont un intérêt considérable pour les agriculteurs dans les systèmes d'élevage pluvial méditerranéen, pour prolonger la saison de pâturage. À l'heure actuelle, dans les systèmes d'agriculture pluviale d'Europe du Sud fondés sur les cultures fourragères annuelles, certaines lacunes dans la disponibilité des fourrages sont présentes au début de l'automne et à la fin du printemps. Dans le but d'évaluer la production de matière sèche et la disponibilité de la biomasse au fil des saisons et des années, des mélanges de fourrage à base de luzerne et de graminées pérennes (fétuque élevée et dactyle) ont été testés pendant trois ans dans un champ expérimental (Sassari – Italie). Le type érigé de luzerne, à la fois dans les peuplements purs et dans les mélanges binaires, a montré les productions les plus élevées parmi les traitements (jusqu'à 12 t de matière sèche par an). Il a également montré la meilleure distribution saisonnière du fourrage, étant capable de croître pendant l'été dans des conditions pluviales, ainsi que durant les hivers doux.*

Mots-clés. *Mélanges de légumineuses-graminées pérennes – Luzerne – Fétuque élevée – Dactyle aggloméré – Rendement fourrager – Tolérance à la sécheresse.*

I – Introduction

In Mediterranean rainfed livestock systems, the use of annual forage crops for grazing is common. In these systems, some gaps in forage availability are present in late spring, summer and early autumn. Growing forage mixtures based on perennial grasses and legumes is one of the available strategies to reduce the forage gap during critical seasons. In fact, grasses are able to produce forage in early autumn, after the first rains, and perennial legumes, i.e. lucerne, boost forage production in late spring and summer. Unfortunately, there is scarce availability of suitable materials for grazing, and of germplasm adapted to drought-prone environments (Porqueddu *et al*., 2016). The objective of our study was to assess the performances of perennial grass-lucerne mixtures based on improved native grass and legume species and varieties in a drought-prone environment in Sardinia.

II – Materials and methods

The field trial was established in October 2013 in the experimental field of CNR-ISPAAM (latitude; 40° 46' N; longitude: 8° 28' E) in Sassari (Sardinia, Italy). The climate of the area is typically Mediterranean with mild winter, characterized by a long-term average annual rainfall of 554 mm, prevailingly distributed in the autumn and winter months, and a mean annual air temperature of 16.2 °C. The soil is alluvial and calcareous, with pH 7.4.

A completely randomized block design with four replications was used. Plots measured 3 x 4 m. Grazing– and drought– tolerant accessions of lucerne ('*Surigheddu*' or L1, erect type; '*Bulk*' or L2, semi-erect type) and grasses (cocksfoot cv '*Kasbah*' or C, true summer dormant type; tall fescue cv '*Flecha*' or F, incompletely summer dormant type) were tested. Their binary (L1C, L1F, L2C, L2F) and 4-component (L1L2CF) mixtures were compared to their respective monocultures (L1, L2, C, F) for dry matter yield (DMY). The seed rates were 25 kg ha^{-1} in lucerne monocultures, 30 kg ha^{-1} in grasses monocultures, half the amounts of each component in binary mixtures and a fourth in the 4-component mixture. In the year of establishment, only one cleaning mowing was carried out. Seasonal cuts were carried out in 2014-2015 (year 1), 2015-2016 (year 2), and 2016-2017 (year 3). The first cut was carried out when lucerne was at the full blooming stage, the following cuts every month. Samples of forage were taken from 2 quadrats (1 m^2 each) in each plot. Samples were weighted and dried up to constant weight in a ventilated oven. The DM was then calculated.

Data were analysed by multifactorial ANOVA. Means were discriminated by the Tukey test ($P<0.05$).

III – Results and discussion

Total rainfall (from September to August of each season) was 469 mm, 418 mm and 436 mm, in year 1, year 2 and year 3, respectively. These values were always below the average annual rainfall. Rainfall was unevenly distributed in the different seasons, with dry and mild winters. Drought lasted at least five months, from April or May to September or October (Figure 1). The average value of mean temperatures in the spring months (March-April) increased from 2014 to 2016 (11.8, 12.2 and 12.4 °C, respectively). This was mainly due to the increase in maximum temperatures (18.3, 19.3 and 20 °C, respectively) while minimum temperatures were similar in 2014 and 2015 (5.2 and 5.3 °C) and lower in 2016 (4.7 °C).

Annual DM yield ranged from 6.9 to 12.7 t ha^{-1} year^{-1} in mixtures, from 7.3 to 11.5 t ha^{-1} year^{-1} in lucerne monocultures, and from 3.5 to 7.1 t ha^{-1} year in grass monocultures. Non statistically significant interactions were found between year and sward type (Table 1). This means that sward productions were almost constant for each treatment during the three experimental years. For this reason, DMYs are reported as three-years DMY averages (Figure 2).

Table 1. Analysis of Variance (F values and significance) for the effects of crop and year and their interactions for sown DMY

Source of variation	F-Ratio
Sward type	22.67***
Year	2.72^{ns}
Sward type x Year	0.48^{ns}

*** = $P<0.001$; ns = not significant.

Several differences were found for DMY among treatments. In pure stands, L1 performed better than L2. DMYs were higher, on average, for Tall fescue F than for cocksfoot C. The latter showed the lowest DM yield among all plots and treatments.

Mixtures based on lucerne L1 showed higher DMYs than L2-mixtures, reaching similar DMYs than L1-pure stands. The L1L2CF mixture yield was statistically similar to L1, L1C and L2F.

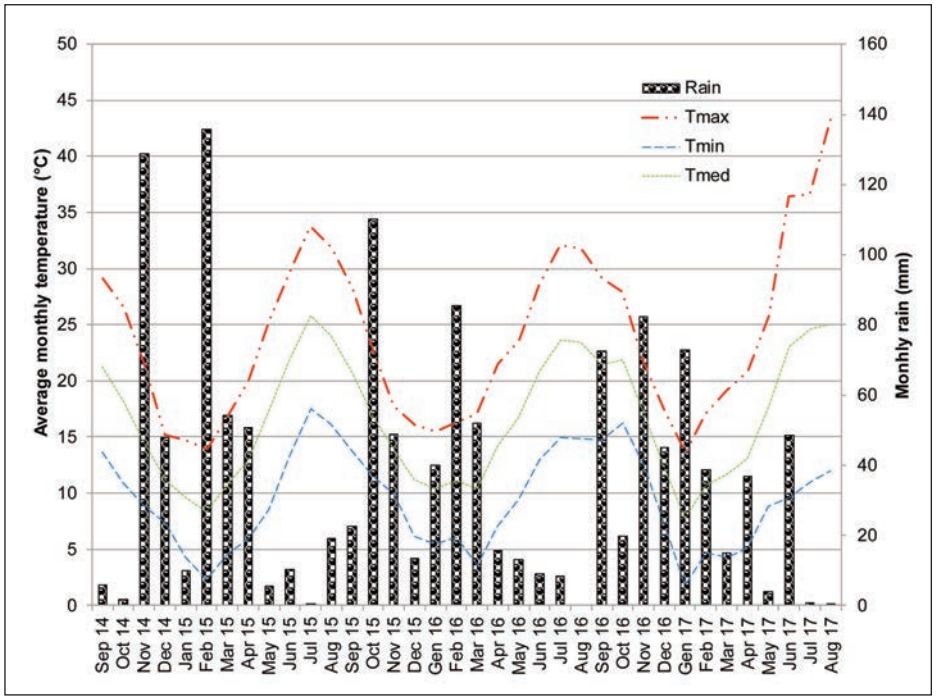

Fig. 1. Meteorological pattern during the three-year experiment.

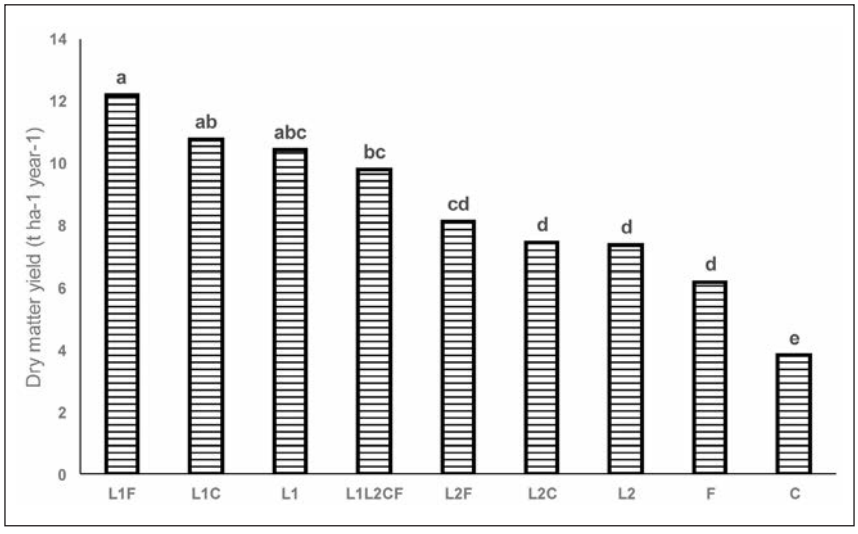

Fig. 2. Three-year average annual DM yield of lucerne and grasses in pure stands and mixtures. Means with same letters are not different at 5% level.

The distribution of forage production among seasons was different in the three experimental years and treatments (Figure 3). L1 produced some DM during the milder winters (year 1 and 2). The contribution of the winter yield was about 30% of the entire annual production of the plot in year 2. Unfortunately, cuts were not carried out in the subsequent spring due to the insufficient forage production. This was shown also in plots where L1-based mixtures were cultivated. Lucerne L2 did not grow in the winter, except for a small forage production in year 1, its growth was mostly concentrated in spring and summer. On average, lucerne monocultures showed the lowest productions in autumn (0.9 t ha^{-1}), when grasses showed the best DMYs (2.3 t ha^{-1}). Despite this, the lucerne-based binary mixtures with F showed similar yields to grasses pure stands (2.4 t ha^{-1}). In winter, no differences were found for DMYs among pure stands and mixtures (1.1 t ha^{-1} in average). In summer, the highest yield was shown by L1 (4.5 t ha^{-1}) and its binary mixtures (4.3 t ha^{-1}), followed by the L1L2CF mixture (3.46 t ha^{-1}) and L2 (3.4 t ha^{-1}) and its binary mixtures (2.2 t ha^{-1}).

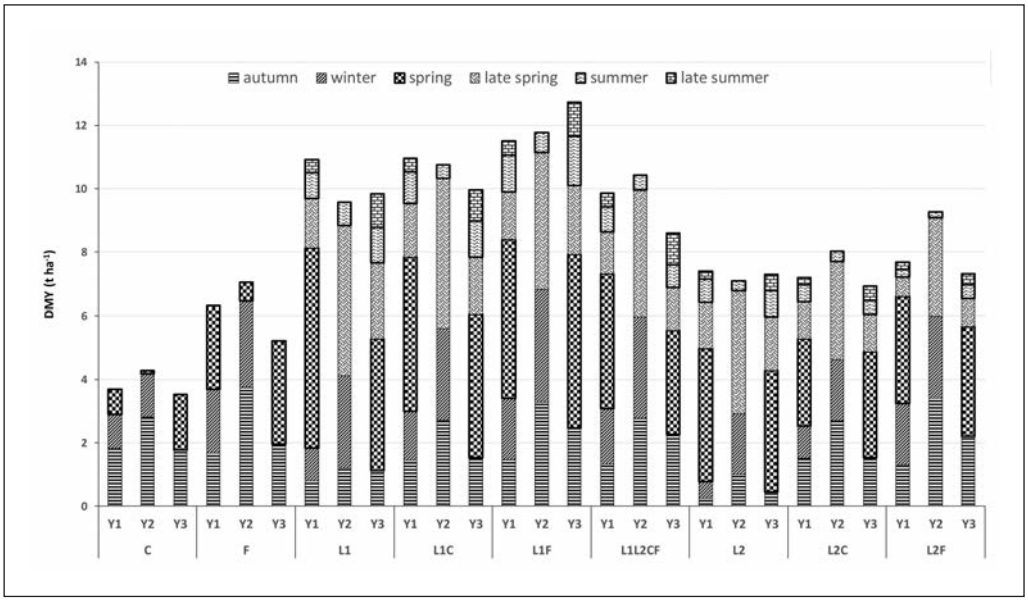

Fig. 3. DM yield distribution in each season and experimental year of pure stands and mixtures of lucerne and grasses.

IV – Conclusions

The potential agronomic advantages of sowing mixtures of forage species and cultivars were confirmed, the main reasons being (i) stabilization of forage production within and between seasons; (ii) achieving a more sustainable grassland management. Moreover, grasses can utilize the nitrogen symbiotically fixed by legumes when grown in mixtures with them, leading to increases also in forage protein yield. Mixtures of summer-dormant and summer-active perennial species provide an opportunity for stable grassland mixtures by exploiting available soil moisture throughout the year (Norton *et al*., 2012). In the plains and low hills with good arable lands of northern Mediterranean basin under rainfed conditions (>450-500 mm), the use of mixtures based on drought-tolerant lucerne and summer dormant perennial grasses improved the seasonal distribution of forage production, increasing the availability of forage during summer and extending the grazing season. Moreover, mixtures are adapted to a mixed use, being suitable for grazing in autumn-winter and for harvesting to produce hay in the spring-summer months.

Acknowledgments

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Voisin's Rational Grazing system for small ruminant feeding in Mediterranean areas

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Abstract. Small ruminant grazing systems in Mediterranean areas are still linked to traditional practices based on continuous grazing, which, in certain cases, lead to a suboptimal exploitation of the herbage and to a reduced economic and ecosystem performance. In South America, for at least 40 years, many farmers have adopted intensive (controlled) rotational or Voisin' s Grazing System (VRG), to maximize the production of aboveground plant biomass and to increase profitability. Using portable and/or permanent fencing and watering systems, VRG consists in applying a high instantaneous stocking density, rotating the animals among paddocks to manage pasture growth and consumption, according to the growth rate of plants, species composition, soil and climatic conditions. The total time that animals occupy a paddock must be very short to prevent the grazing of regrowth in the same residence time. This technique, recently applied by small ruminant farmers, makes it possible to: (i) regenerate degraded pastures and meadows in marginal areas, (ii) increase harvesting efficiency and productivity of lowland pastures, (iii) obtain a diet more stable and of higher quality for livestock, (iv) increase the stock of carbon in soils, and (v) enrich plant and animal biodiversity as a result of increased soil fertility. From the literature, we draw some examples of VRG application in ruminant production, considering the most recent research works and independent observation, with the aim of listing the benefits that have been verified in terms of productivity, mitigation of CO_2 emissions and effects on the ecosystem, as well as the possibilities of adoption in the Mediterranean basin.

Keywords. Voisin's grazing system – Livestock sustainability – Grazing management.

Pâturage tournant intensif pour l'alimentation des petits ruminants en régions méditerranéennes

Résumé. *Les systèmes de pâturage des petits ruminants dans les régions méditerranéennes sont encore liés aux pratiques traditionnelles basées sur le pâturage continu, qui, dans certains cas, conduisent à une exploitation inefficace de l'herbe et à des performances économiques et écosystémiques médiocres. En Amérique du Sud, depuis au moins 40 ans, de nombreux agriculteurs ont adopté le système de rotation intensif (contrôlé) de Voisin (VRG), afin de maximiser la production de biomasse aérienne des plantes et d'augmenter la rentabilité de leur élevage. Utilisant des clôtures et des systèmes d'arrosage portables et/ou permanents, le VRG consiste à appliquer un chargement instantané élevé, en faisant tourner les animaux entre parcs pour gérer la croissance et la consommation des pâturages en fonction de la vitesse de croissance des plantes, des espèces présentes, des conditions pédoclimatiques. Le temps de séjour sur un parc doit être suffisamment court pour éviter le pâturage de repousses durant un même passage. Cette technique, récemment appliquée par des éleveurs de petits ruminants, permet de : (i) régénérer les pâturages et prairies dégradés dans les zones marginales, (ii) accroître l'efficacité de la récolte et la productivité des pâturages de basse altitude, (iii) obtenir un régime alimentaire plus stable et de meilleure qualité pour le bétail, (iv) accroître le stock de carbone dans les sols et (v) enrichir la biodiversité végétale et animale, grâce à l'augmentation de la fertilité des sols. Nous proposons quelques exemples d'applications du VRG dans la production de ruminants, en prenant en compte les travaux de recherche les plus récents et des observations indépendantes, dans le but de répertorier les avantages vérifiés en termes de productivité, de réduction des émissions de CO_2 et d'effets sur l'écosystème, ainsi que les possibilités de mise en œuvre dans le bassin méditerranéen.*

Mots-clés. *Pâturage Rationnel Rotatif – Durabilité – Gestion du pâturage.*

I – Introduction

Pasture-based farming systems have undergone an evolution in recent decades, in terms of intensification, structural, economic, social and environmental factors. Special attention has been paid to critical points for sustainability. However, in the Mediterranean area, less attention has been devoted to the management of grazing systems in relation to grass productivity/nutritional characteristics and animal production responses, as well as the best options to be taken depending on the local context.

Among different rotational grazing techniques (Bernués *et al*., 2011), the Voisin's Rational Grazing (VRG) system (Voisin, 1959), represents an intensive management of pastures, with two main rules: (i) rest and stocking periods must vary with the growth rate of plants; (ii) the total time that animals occupy a paddock must be very short to prevent the grazing of regrowth in the same residence time. Recently, Pinheiro Machado (2010) added some technical recommendations, such as planting trees, diversifying species in all paddocks, no tilling of the soil, and no use of agrochemicals. The rotation of ruminants among paddocks, by means of portable fencing, allows a variable rest period, which must be sufficiently long to allow the plants to completely re-grow. The introduction of animals in the individual paddock is carried out with at high density and with a very short residence time, ranging from 12 hours to 3 days.

This technique is widespread in Latin America, mainly for beef and dairy cattle farming, as well as for small ruminants (Fig. 1). It is conceivable that with appropriate adaptations, this technique could also be used in the Mediterranean environment. In this paper we review some of the theoretical advantages of VRG.

Fig. 1. Sheep in a Voisin's Rational Grazing system, "El Mate" farm, Cordoba (Argentina). Photos courtesy of Bruno Basquetto.

II – Methods and theoretical framework

A literature review was carried out to identify those publications reporting VRG system with small ruminants and cattle. The selection of publications was performed with a research on the Internet using the current databases available (Scopus, Science Direct, Google Scholar and Google). In this review, according to the scientific and technical literature, we focused on the VRG system and its effects on herbage productivity and pastoral value, animal performance and ecosystem services, including carbon sequestration and biodiversity conservation.

III – Evidences from the literature

1. Pasture characteristics and animal performance

One of the means by which VRG systems are claimed to increase animal performance, is to improve the productivity of above-ground biomass and the nutritional quality of pasture. Feria *et al*. (2002) compared VRG, rotational and continuous grazing systems for fattening cattle, concluding that VRG increased the production of dry matter of about 30 to 40% compared to continuous grazing with different rainfall regimes (Table 1).

Table 1. Seasonal grass availability (in kg dry matter/animal/d) as a function of grazing management Feria *et al*., 2002

Season	VRG	Rotational grazing	Continuous grazing	SD
Scarce rainfall I	18.4[a]	15.7[b]	13.2[b]	1.2*
Rainy season	23.2[a]	20.1[b]	18.6[b]	0.9**
Scarce rainfall II	19.7[a]	14.5[b]	13.1[b]	0.3**

[ab] Uncommon letters in the same row differ for P < 0.05; * P < 0.05 ** P < 0.01.

The analysis of the nutritional value of herbage in the dry season, showed a higher crude protein in VRG (8.31%) compared to the other grazing systems (7.02% and 6.17%) (Table 2).

Table 2. Chemical composition of the herbage during the dry season (whole plant). Feria *et al*., 2002

Grazing system	DM%	CP%	CF%	Digestibility %	Ash %
VRG	35.05	8.31[a]	31.53	54.00	7.45[a]
Rotational grazing	38.57	7.02[b]	33.41	53.00	7.93[b]
Continuous grazing	36.33	6.17[c]	33.76	52.94	9.71[b]
SE	0.93	0.35**	1.19	0.91	0.50*

[abc] Uncommon letters in the same column differ for P <0.05; * P <0.05 ** P <0.01. DM: Dry Matter; CP: Crude Protein; CF: Crude Fibre.

Donnola (2018) estimated the difference in grass production for grazing dairy cows in *Pian Cansiglio* (Veneto, Italy). The results were 2,500 kg DM/ha/year in the case of continuous grazing, 5,500 and 6,000 kg of DM/ha/year for the first two years of application of VRG, which represents a productivity increase of more than 100%.

It is known that cattle and sheep grazing at high stocking densities tend to be more voracious, avoiding selective grazing, conversely to free grazing. This change in feeding behaviour results in natural weed control and in an increase in the number of plants per square meter. The increase in the number of species and the greater density of plants progressively increases the nutritional quality of the pasture (Feria *et al.,* 2002).

Feria *et al*. (2002) found significant differences in beef daily weight gain, with 0.51 kg/head/day for VRG compared to 0.41 kg and 0.42 kg in rotational grazing and continuous grazing systems, respectively. More recently, Kuhnen *et al*. (2015), observed a lower milk production in VRG-fed cows compared to a more intensive feeding regime, but with substantial benefits in terms of farm income and ecosystem services. Ojeda-Falcón *et al*. (2018), reported that the stocking density in a farm in the province of Santa Fe (Argentina) practising VRG in the last 18 years, reached 4.35 Animal Units/ha, which is over 4 times the typical grazing load of the area.

2. Ecosystem services

The increase in biomass production directly generates an increase in the fixation of CO_2 from the atmosphere by the plants. Seó *et al*. (2017) found that VRG can stock more carbon than no-tillage (NT) fields (VRG = 115.0 Mg C ha^{-1}; NT = 92.5 Mg C ha^{-1}; $p < 0.00009$), with the greatest difference at a depth of 0-10 cm (VRG = 41 Mg C ha^{-1}; NT = 32 Mg C ha^{-1}; $p < 0.00008$). In VRG, 95% of C was in the soil, 1% in the aerial part of plants, and 4% in the roots. In terms of production performance, VRG produced 0.15 kg of milk kg^{-1} of C stored, and NT 0.13 kg of milk kg^{-1} of C stored.

Sanchez *et al*. (1996) reported that the quantity of insects in the soil decreased from 75% to 35.5% from the moment of the beginning of VRG to 4 years after its application. Insects decreased due to the large increase in oligochaetes in a proportion of 32.2% together with the appearance of other groups such as diplopods, isopods, and arachnids belonging to the Myriapoda, Crustaceae and Arachnida classes respectively, with a net contribution to increasing edaphic biodiversity. The authors concluded that the biomass of such groups after the application of VRG was 11.25 times higher than to that before the start of the experiment.

The increase in the number and proportion of plants, added to a lower total trampling, maintains highly fragile ecosystems in more stable situations, avoiding erosion, desertification and invasion. Rojas Paez and Zulay (2016) assessed the soil loss of continuous grazing and VRG with cattle, and concluded that VRG, with one-day occupations, generates less long-term soil losses due to the shorter residence time. VRG would also increase plant biodiversity. Hack *et al*. (2009) evaluated the floristic composition of a natural meadow grazed with VRG and continuous system, observing a greater diversity in the floristic composition for the first one.

IV – Conclusions

This review confirms that the VRG is a strategy to be considered also for Mediterranean environments and small ruminant production. Although the works reported were carried out with cattle, various personal communications and informal publications confirm these same benefits in the application of the VRG technique with sheep and goats. Unfortunately, no specific publications have been found and the literature remains rather limited, with many knowledge gaps as for example profitability, workflows, self-reliance, resilience, adaptation to climate conditions, animal welfare and hazards.

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The north-western grasslands of Tunisia; a feed resource to efficiently produce a healthy sheep meat

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Abstract. In the North West region of Tunisia, lambs are produced indoors (S) or at pasture (P).The main meat breeds are: *Barbarine* (BB), *Noire de Tibhar* (NT) and *Queue Fine de l'Ouest* (QFO). This study investigated the effects of feeding system (S *vs.* P) and breed (BB, NT, QFO) on lambs' growth and carcass and meat quality. 36 male lambs (20 kg body weight) were used. S lambs received an increasing amount of concentrate (300 to 600g) with 500g of oat hay. P lambs ingested the same amount of hay and grazed for 6 hours in natural grassland for which the botanical composition was determined. After 67days, the lambs were slaughtered, carcasses were dissected and meat quality was studied. The pasture was composed of 45% grasses, 14% legumes and 41% other species. The average daily gain (ADG) was lower for P than for S lambs (94 vs. 111 g/day). The NT breed had the highest ADG (125 g/day). P lambs accumulated more muscle and less fat than S lambs, with no difference between breeds. In contrast, although the meat of both feeding systems had the same macro-chemical composition, saturated fatty acids and lipid oxidation index of meat were higher in S than in P meat.

Keywords. Natural grassland – Sheep – Performance – Meat quality – Breed.

Les prairies du nord-ouest de la Tunisie : une ressource alimentaire pour produire efficacement une viande ovine saine

Résumé. Aunord-ouest de la Tunisie, les agneaux sont produits en bergerie (S) ou aupâturage (P). Les races à viande sont: la *Barbarine* (BB), la *Noire de Tibhar* (NT) et la *Queue Fine de l'Ouest* (QFO). Cette étude a examiné les effets du systèmealimentaire (S vs. P) et de la race (BB, NT, QFO) sur la croissance, la qualité de la carcasse et de la viande. 36 agneaux mâles (20 kg de poids vif) ont été utilisés. Les agneaux S recevaient une quantité croissante de concentré (300 à 600 g) avec 500 g de foin d'avoine. Les agneaux P ingéraient la même quantité de foin et pâturaient pendant 6 h sur une prairie dont la composition floristique avait étédéterminée. Après 67 jours, les agneaux ont été abattus, les carcasses disséquées et la qualité de la viande étudiée. La prairie était composée de 45% de graminées, 14% de légumineuses et 41% d'autres espèces. Les agneaux P avaient le gain moyen quotidien (GMQ) le plus bas (94 vs.111 g/jour), et la race NT le GMQ le plus élevé (125g/jour). Les agneaux P avaient accumulé plus de muscleet moins de gras que les agneaux S, sans différence entre les races. En revanche, bien que la viande des deux systèmes alimentaires ait la même composition macro-chimique, les acides gras saturés et l'indice d'oxydation lipidique de la viande étaient plus élevés pour S que pour P.

Mots-clés. Prairies naturelles – Ovins – Performances – Qualité de la viande – Race.

I – Introduction

In North-western areas of Tunisia, natural grasslands have been increasingly exploited in sheep farming as an alternative to concentrates, mainly due to the increase of cereal prices and to satisfy the societal demands regarding environmental and ethical concerns about food production (Bernués *et al.*, 2011). The objectives of this study were to estimate grassland production in these areas and to acknowledge the impact of such feeding system on the growth of lambs and carcass and meat quality.

II – Materials and methods

1. Animals, diets, slaughter and sampling procedures

A total of 36 male lambs (4 months old; 20.3 ±1.9 kg body weight) were used: 12 from the fat-tailed *Barbarine* (BB) breed, 12 from the thin-tailed *Queue Fine de l'Ouest* breed (QFO) and 12 from the thin-tailed *Noire de Thibar* breed (NT). Lambs from each breed were allocated on the basis of BW to one of two feeding systems : pasture (P) *vs.* stall (S).The three S groups received increasing amounts of concentrate (72% barley,25% faba bean and 3% mineral and vitamin; 300 to 500g) and oat hay (300 to 600 g). The P groups received the same amount of oat hay and grazed for 6 h daily, 2500 m^2 of natural grassland. After 67days, all lambs were weighed (after fasting) to measure body weight at slaughter (SBW), and then slaughtered. The carcasses were placed in a chiller at 4°C for 24 hours, after which each carcass was split along the midline, cut in six joints to be dissected in order to determine carcass tissular composition and *Longissimus Dorsi* (LD) muscle was removed to study meat quality.

2. Measurements and analysis

Oat hay and concentrate intake were recorded daily. For P, biomass availability at pasture was estimated according to the dry-weight-rank method (Tothill *et al*., 1992) and biomass intake was estimated based on the palatability of the dominant species. Samples of meat were dried, ground and analyzed for dry matter (DM), nitrogen (N), ash and intramuscular fat (IMF).Fat extraction to determine fatty acid profile was carried out according to the method of Bligh and Dyer (1959). Lipid oxidation (thiobarbituric acid reactive substances) during 6 days of storage was determined according to Botsoglou *et al*. (1994) and data was analyzed using the MIXED procedureof the Statistical Analysis Systems (SAS, 1999).Data related to the rest of the parameters was analyzed using the GLM procedure to assess the effects of feeding systems, breeds and their interaction.

III – Results and discussion

The feeding system x breed interaction was not significant, for all parameters.

1. Growth performance and carcass tissue composition

The grazed flora was composed of 45% grasses, 14% legumes and 41% other species (mainly 30% thistle). Indoors, lambs of different breeds consumed the same amounts of concentrate(P >0.05) with an average of 570 g. For P lambs, the stockingrate was 72 lambs/ha, allowing an averagegrass intake ofabout 560 g DM per lamb and per day (22g DM/kg BW) (Bouazizi et Mahjoub, 1999). This intake was covered by the biomass offered that was estimated to be1.2 and 2 kg/lamb at the beginning and the end of the trial. The oat hay intake was 440 g of DM. P Lambs had lower average daily gain (ADG) than S lambs (111 v. 94 g, Table1). The NT breed had higher SBW (27.99 kg; P < 0.01) and ADG (125 g/day, Table 1) than both other breeds. Besides, both farming system and breed affected the tissue composition of carcasses. In fact, fat content was higher for S than for P lambs and the BB breed had more subcutaneous fat than thin-tailed breeds (Table 1).

2. Meat chemical composition

The difference in lipid content in the meat of S lambs compared to P lambs was not significant. However, S lambs had more intramuscular fat than P ones which may be explained by a higher energy expenditure during grazing (Atti and Mahouachi, 2009).The breed affected (P = 0.01) both intramuscular lipids and protein content. Meat from the NT breed had the highest protein and the lowest fat content (79.95 and 18.68 %, respectively; Table 1).

Table 1. Effect of feeding system (FS) and breed on growth performance of lambs, carcass tissue composition and *longissimus dorsi* (LD) muscle chemical composition

	Breed[1]		Feeding system			Statistics[2]	
	BB	QFO	NT	P	S	Breed	FS
IBW (kg)	19.75	19.87	21.16	20.30	20.26	ns	ns
SBW (kg)	25.05^{b}	25.00^{b}	27.99^{a}	25.32	26.71	**	ns
ADG (g)	93.1^{b}	90.5^{b}	124.7^{a}	94.5 ^{b}	111.1^{a}	**	*
Muscle (%)	52.97^{a}	56.10^{a}	55.46^{a}	57.38^{b}	52.56^{b}	*	***
Intermusular fat (%)	7.39^{a}	7.42^{a}	6.27^{a}	4.88^{b}	9.04^{a}	ns	***
Subcutaneous fat (%)	7.77^{a}	4.59^{b}	3.84^{b}	3.39^{b}	7.15^{a}	***	***
DM in LD(%)	25.72^{a}	25.47^{a}	25.13^{a}	24.48^{b}	26.33^{a}	ns	*
Proteins in LD (%)	71.78^{a}	70.64^{a}	79.95^{b}	73.89^{a}	72.84^{a}	**	ns
Lipids in LD (%)	23.67^{a}	24.56^{a}	18.68^{b}	21.37^{a}	22.75^{a}	**	ns

[1] BB: Barbarine ; QFO: Queue Fine de l'Ouest ; NT: Noire de Thibar ; ^{a,b} Values within a row with different superscripts differ significantly at $P< 0.05$; IBW: initial Body weight; SBW: slaughter body weight; ADG: average daily gain; *ns:* $P>0.05$*; *:* $P<0.05$*; **:* $P<0.01$; ***: $P< 0.001$.

3. Fatty acid profile

The saturated fatty acids (SFA) content was higher for the S groups than for P ones (50.63 vs. 44.48 %; Table 2). Breed affected SFA concentrations (Table 2). C10:0 and C16:0 fatty acids were higher for the BB breed and C20:0 were higher for the NT breed. C14:0 and the C16:0 SFA are not recommended for human consumption (Costa *et al*., 2011). Total poly-unsaturated fatty acids (PUFA) content was affected by feeding system in favor of the P groups (18.06 vs. 6.97; Table 2). Individual PUFA were not affected by the genetic type.The n-6 PUFA were higher for S, while the n-3 PUFA were higher for P (Table 2). Thus, we confirmed that grass is a good source of n-3 PUFA, as suggested in the scientific literature (Yousefi *et al*., 2012). The n6/n3 and the PUFA/SFA ratios were affected by feeding systemin favorto the P groups. The percentage ofdesirable fatty acids was significantly higher in P meat than in S meat (72.66 vs. 66.84 %; Table 2), which is also consistent with the available scientific literature (Wood *et al*., 2004; Costa *et al*., 2011).

Table 2. Fatty acid ratios of intramuscular fat of lambs

	Breed[1]		Feeding system			Statistics[2]	
	BB	QFO	N	P	S	Breed	FS
∑ SFA	48.21	47.82	46.95	44.48	50.63	ns	**
∑ PUFA	12.4	11.81	13.10	18.06	6.97	ns	***
∑ n6	8.46	8.057	9.18	11.96	5.37	ns	***
∑ n3	1.49	2.51	2.73	4.26	0.99	ns	***
Desirable fatty acids	69.47	67.75	71.76	72.66	66.84	*	***
n6/n3	4.38	3.80	4.34	2.73	5.54	ns	***
PUFA/SFA	0.27	2.26	0.28	0.42	0.14	ns	***

1 : BB= Barbarine ; QFO= Queue fine de l'ouest ; NT= Noir de Thibar ; 2: Breed= breed effect; Diet= diet effect SFA:saturatedfattyacids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; Desirable fatty acids: 18:0 + unsaturated fatty acids.

4. Lipid oxidation

The evolution of the amount of thiobarbituric acid reactive substances (TBARS) were similar between breeds on the first day(P= 0.002). However, on the 3rd day meat from the QFO breed was more oxidized than meat from BB and NT breeds. This difference lasted for the 6 days of storage and the QFO breed displayed the highest lipid index (1.31 mg MDA/kg). These results confirm pre-

vious findings reporting that differences in the amount of total fat and PUFAs had little effect on the oxidative stability of raw meat. From the first to the third day of storage, meat from the S group had the highest lipid oxidation (0.112 *vs.* 0.048 and0.623 *vs.* 0.370 mg MDA/kg meat, at 0 and 3 days of storage, respectively). This difference was probably due to the higher concentration of antioxidant molecules in green herbage (Wood *et al*., 2004). In the present study, the effect of these substances decreased at 6 days of storage.

IV – Conclusions

Feeding light lambs with concentrate (S) or at pasture (P) in north-western Tunisia lead to similar growth rate and concentrations of lipids and proteins in meat, although P carcasses were leaner and P meat had a longer shelf-life than S meat.

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Fertilization improves the production of natural wet grasslands in the oriental High Atlas mountains of Morocco: the case of *Imilchil* region

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Abstract. The oriental High Atlas mountains in southeast of Morocco are characterized by small areas of natural wet grasslands called *Almo*. These are well managed by the local population in order to feed cattle and mullets. Under the framework of a research and development project, a trial was implemented in order to assess the effects of nitrogen fertilization on the phytomass production of the natural wet grasslands of *Tissila* (6.5 Ha) in the *Imilchil* region. The experimental design consisted in dividing the grassland into three plots: a "control" plot (P1, without fertilisation) and two experimental plots which received two different doses of nitrogen split in three applications during the year. The first plot (P2) received a cumulated amount of 134 kg N/ha plus 46 Kg P2O5/ha in two applications; the second plot (P3) received a cumulated amount of 67 kg N/ha plus 46 Kg P2O5/ha, applied similarly to P2. The phytomass production doubled with fertilization, even at the lowest dose (P3). The assessment of flora revealed a great specific richness (79 species) and some endemism which should be preserved.

Keywords. Grassland – Meadow – Fertilization – High Atlas – Floristic diversity.

***La fertilisation augmente la production des prairies humides dans les montagnes orientales du Haut-Atlas : cas de la region d'*Imilchil**

Résumé. *Les montagnes orientales du Haut Atlas au sud-est du Maroc sont caractérisées par de petites parcelles de prairies humides naturelles appelées* "Almo". *Celles-ci sont bien gérées par la population locale et destinées à nourrir les bovins et les mulets. Dans le cadre d'un projet de recherche/développement, un essai a été réalisé afin d'évaluer les effets de la fertilisation azotée sur la production de la prairie de* Tissila *(6,5 Ha) dans la région d'*Imilchil. *Le plan expérimental consistait à diviser la prairie en trois parcelles : une parcelle laissée comme témoin (P1) et deux autres recevant deux doses d'azote pendant trois périodes de l'année. L'une (P2) recevait un total de 134 kg N / ha en trois applications (sulfate d'ammonium en octobre + urée en avril et mai) plus 46 kg de P2O5 / ha en deux applications (superphosphate triple en avril et mai); l'autre (P3) recevait un total de 67 kg N / ha plus 46 kg P2O5 / ha, dans les mêmes conditions d'application que P2. La production de pyhtomasse a doublé sous l'effet de la fertilisation, même à faible dose (P3). L'évaluation de la flore a révélé une grande richesse spécifique (79 espèces) et des espèces endémiques qui méritent d'être sauvegardées.*

Mots-clés. *Prairie – Fertilisation – Haut Atlas – Diversité floristique.*

I – Introduction

Agdals in *Tachelhit* language (Berber) means a collective pastureland whose opening and closing are operated at fixed dates by the community of users (Bourbouze, 1997; Auclair & Alifriqui, 2005). *Almou* (or *Ilmouten* – plural) is a special form of *Agadal* that consists of mountain meadow, an increasingly rare habitat. *Almous* are an open habitat natural vegetation composed by non-woody plants (herbaceous, perennial or annual species) from different plant families mainly grasses and legumes (Bourbouze, 1997). They are grazed by cattle and mules ("*tiwili*" system), rarely by small ruminants. In our study site, *Tissila Almou* is managed by one tribe of the village (lineage status) and based on traditional laws implemented by the local population (users).

The vulnerability of these wet grasslands requires the implementation of adaptive strategies for their preservation and the restoration of their ecological balance. As a result, grassland fertilization trials were carried out within the framework of an agreement of a PDRME (Rural Development Project of Mountain Areas of Errachidia Province)project between the Regional Office for Agricultural Development of Tafilalet (ORMVA-TF) and the National Institute for Agronomic Research (INRA).

Many studies have shown that a correct mineral fertilization plays a positive role in the production and quality of pastoral and forage species (Delaby 2000, Leconte 2002, Durant & Kernéïs 2015).The aim of the study was to demonstrate to the local population how to increase productivity and quality of meadows by a reasoned fertilization and to deal with the alarming situation of the cultivation of highland grasslands and the abandonment of their traditional management system.

II – Materials and methods

The study took place in the mountain area of *Imilchil* (32°06 N; 005°33W, 2213 m a.s.l.). This area is part of a strategic ecological situation of the Eastern High Atlas characterized by water sharing in four watersheds: *Um-Errabia, Ziz, Moulouya* and *Gheris*. The area is characterized by a semi-arid bioclimate with cold winters and snowfall. The average rainfall is 317 mm at *Ilmilchil*. The average minimum temperature is -5.1 ° C, the average maximum temperature 32.4 ° C and the average annual temperature 11.0 °C.

The *Tissila* wet grassland extends over 6 ha; for the purpose of this study, it was divided into 3 plots: P1 (unfertilized control), P2 (high fertilisation), P3 (moderate fertilisation) (Table 1). The spreading of fertilizers was done manually.

Table 1. Quantities and dates of fertilizer application (kg/ha) in Year 1. In Year 2 rates were halved

Plots	Date of spreading	Ammonium sulphate *	Urea**	TSP***
P1	Beginning of October	0	0	0
	Beginning of April	0	0	0
	End of May	0	0	0
P2	Beginning of October	100	0	0
	Beginning of April	100	100	50
	End of May	0	100	50
P3	Beginning of October	50	0	0
	Beginning of April	50	50	50
	End of May	0	50	50

* $(NH_4)_2SO_4$; ** CH_4N_2O : Urea; *** $Ca(H_2PO_4)$ $2.H_2O$: Triple superphosphate (TSP).

Trials were carried out in 2011/2012 and 2012/2013. The plots were monitored for two years, but during the second year, only half of the fertilizers doses were applied.

Soil samples were analysed in terms of water, organic matter (OM), mineral content and pH.

Phytomass was estimated on 40 quadrats of 1m² using the method of the Reference Unit (UR), which consists in choosing a typical grass bouquet from the plots to be sampled (we took 1/8 of each 1m² quadrat). The samples were dried at 65 ° C for 72 hours then weighed to obtain their dry matter (DM).

A qualitative and quantitative inventory of botanical composition, following the Braun-Blanquet (1932) method, was performed on aligned quadrats points of 1 m x1 m along the diagonal of each plot. The parameters calculated from the linear survey in each quadrat were:

- Overall vegetation cover (**RGV**) expressed as a percentage: **RGV (%) = 100 x Ni /N**; Ni: Number of points with vegetation cover and N: Total number of points / quadrat;
- Specific frequency (**FSi**) for each species i: **FSi (%) = 100 x ni/N**; ni = Number of points where species i is encountered and
- Specific contribution (CSi): **Csi (%) = 100 x ni/ NI**;
- Σni = Number of points where vegetation came across = Ni.

The second step was to calculate floristic diversity indexes. The **Shannon-Weaver Index** (Shannon & Weaver, 1949) is the simplest in $H' = -\sum_{i=1}^{n} p_i \log_2 p_i$ its category and, therefore, the most widely used, with S = total number of species; pi = (nj/N), relative frequency of species; nj = relative frequency of species j in the sampling unit; N = sum of specific relative frequencies. The higher the value of H', the greater the diversity.

The measure **of evenness** (or uniformity) (E) is useful for detecting changes in the structure of a community and has sometimes proven effectiveness in detecting changes of anthropogenic origin: **$E = H'/\log_2 S$.** When all species are equally abundant, an evenness index would be at a maximum and decrease towards zero as the relative abundances of the species diverge away from evenness.

The dominance indices, using Simpson's index $D = \sum_{i=1}^{n} p_i^2$ as a most widely used index (Simpson, 1949): Specific diversity is highest when Simpson's index is lowest.

The data collected were subjected to statistical analyses under Excel and SPPS. As a rule, at least 10 measurements were used to obtain an average for each parameter.

III – Results and discussion

1. Soil analyses

Based on the soil analyzes presented in Table 2, there was little physical and chemical variability among the *Tissila* plots. The soils had two different textures. Organic matter richness and mineral content were also variable from one plot to another.

Table 2. Physical and chemical properties of the soils of the *Tissila* meadow plots

Plots	Particles % on the dry ground					Particle % on the mineral part				Texture
	%C	%FL	%CL	% FS	% CS	%Lim	%C	%L	% S	
P1 (T)	31.5	18.7	6.4	5.7	3.4	34.4	48.0	38.2	13.8	HC
P2 (200)	29.7	27.3	8.5	3.4	0.8	30.3	42.6	51.3	6.1	CL
P3 (100)	31.5	19.9	5.5	7.1	1.1	34.9	48.4	39.0	12.6	HC
	Depth (cm)		pH (eau)	pH (KCl 1 N)		OM (%)		P_2O_5 (ppm)		K_2O (ppm)
P1 (T)	0-35		7.9	7.5		1.6		35.1		134.9
P2 (200)	0-35		8.0	7.7		0.8		19.4		64.0
P3 (100)	0-35		7.6	7.1		3.1		36.3		112.7

C: Clay; FL: fine Loam; LG.: Coarse Loam; FS: fine sand ; CS: Coarse Sand; L: Loam; S: Sand; Ca: Limestone / Texture: OHC: Heavy clay, CL: Clay Loam. OM: Organic matter.

2. Floristic analysis

The presence of the meadow on the valley and the possibility of its irrigation make the natural vegetal very dense and diversified. Average overall aerial vegetation cover was between 90-100%. The plant facies was clearly dominated by graminaceous species. The dominant species in the floris-

tic composition was *Lolium multiflorum* (local name: *Agassisse*). Other dominant species were: *Eleocharis palustris* (l.) Roem. & Schult from the genus Eleocharis and *Alopecurus pratensis*. It should also be noted that P3 was dominated by *Lolium multiflorum* and co-dominated by *Ranunculus bulbosus* L.

The dominance of grasses does not seem to affect the botanical diversity of the grassland. Thus, many annual and perennial species go with dominant species especially on the borders. These species belong to 23 families, including Fabaceae, Poaceae and Plantaginaceae as predominating families. The grassland contains a very remarkable orophilic vegetation, rich in endemic species due to the local micro-climate and the geomorphology of the site. These plant formations based on hemichrophyres (49%) are characterized by a very high overall vegetation cover. In addition to the richness, the pastoral quality seemed good due to the presence of both grasses and legumes. Prospection and inspection of the site suggest that some species, such as plantain (*Plantago* sp.) mainly in the border, *Ononis spinosa* subsp. Antiquorum (L.), *Arcangeli* and *Cirsium pyrenaicum* (Jacq.) inside the meadow indicate an overexploitation. Also, the bad distribution of irrigation water and the dominance of *Ranunculus bulbosus* in some parts of the meadow (lower part: plot 2) indicate that the soil is poor and receives a contrasting water regime suffering from the summer drought.

The overall species richness of the meadow is 79 species recorded during the maximum vegetation (14 excluding borders) of the second year of monitoring (2013). The analysis of floristic diversity parameters (Fig. 1) indicates that the fertilized plots have a relatively higher floristic richness compared to the control. The Shannon and Weaver index varied in the plots between 3.1 to 3.4, showing that biodiversity in the meadow is relatively high with the co-dominance of several species (Simpson's dominance index tends to 0). The regularity indicated by the Pioucha J' evenness index (tends to 1) is rather good (numerical representation of the different taxa). However, longer term measurements are needed to assess the impact of fertilisation on the floristic composition of these grasslands.

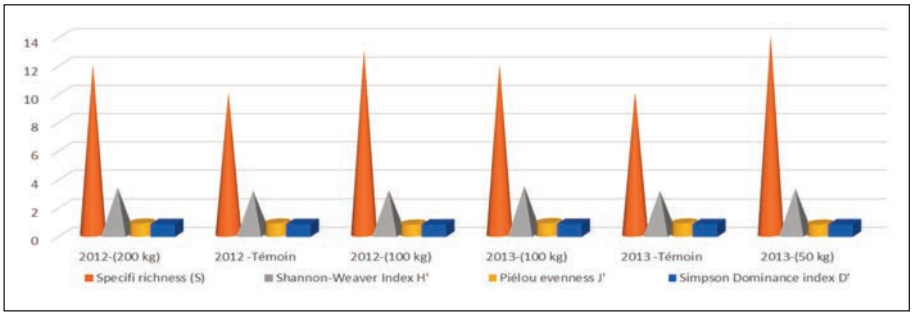

Fig. 1. Indexes of floristic diversity of the *Tissila* meadow according to fertilization doses and year of fertilizers spreading.

3. Production and feed availability of the meadow

The measurement of phytomass showed interesting results of the effect of fertilization on grassland production. In fact, the phytomass of the fertilized plot 3 doubled in terms of production compared to the control during the first year, whereas during the second year, the increase in plot 2 over the control is 33% only using the half of the dose (100 kg N / ha), (Fig. 2). The same result was obtained for plot 2 (34%) which received the rate of 100 kg N / ha in the first year.

Fertilization has certainly improved the productivity and vigour of the meadow, but the confounding effect of the heterogeneity of water irrigation and the variation of biodiversity lead suggest that a big amount of fertilizers is not necessary.

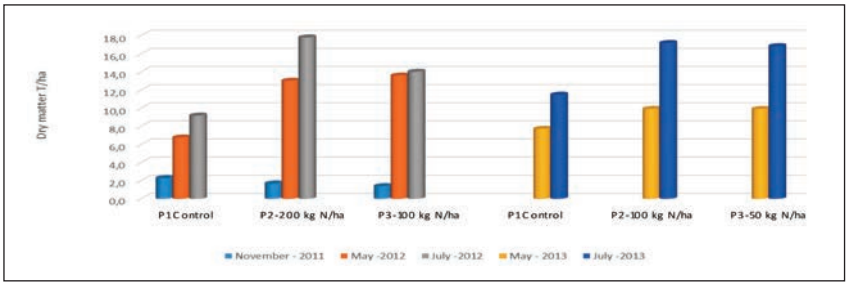

Fig. 2. Phytomass in the three tested plots according to doses and years of fertilizers spreading.

4. Available forage and economic study of meadow fertilization

According to the local knowledge of local population, almost all species are grazed by cattle and 80-95% of the production is consumed: plants height before pasture is about 80-150 cm while after pasture it is about 8-10 cm. This indicated at the species forming the meadow are very resistant to grazing. The economic net gain in production provided by the applied fertilization compared to the control plots is summarized in Table 4. For net gain (Dh/ha), we calculated for each parcel the production in kg, then the offered forage units (UF) according to the pastoral value of each parcel, then we subtract the average production for example of parcel 2 to the control; we assimilated 1 UF to 1 kg of barley to estimate prices.

According to Table 4, fertilization application is largely justified (despite the prices are increased) since the estimated minimum net gain is 18139 dh/ha for plot 3 compared to the control. A gain of four tons of production at the level of all the meadow was obtained which is enough to cover the highest charges of the applied fertilization.

Table 4. Estimation of the net gain of the fertilized meadow of *Tissila* compared to the control and according to the applied doses

	P2 (200)	P3 (100)	P2 (100)	P3 (50)
Net gain of *Tissila* meadow per hectare (Dh/ha)	31257	18139	22869	20355

IV – Conclusion

The study undertaken on Tissila Meadow highlighted a remarkable floristic diversity that deserves to be preserved. The results of targeted nitrogen fertilization showed a significant improvement in the productivity. The results show that the costs of fertilizers are largely offset by the improved production. However, an in-depth diagnosis of the meadow in a more comprehensive approach taking into account different aspects deserves to be done to remove constraints, ensure sustainability and optimize production through the adjustment of the animal stocking rate, control of soil fertility and the management of spatial heterogeneity.

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Developing a toolbox for rangeland restoration/rehabilitation in arid environments

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Abstract. Rangelands are recognized for their importance and value in providing society with valuable products and ecosystem services. In such ecosystems, effective management is needed for sustainable plant growth and survival in a context characterized by rainfall unreliability, poor soil nutrient status and high uncontrolled grazing. Therefore, cost-effective techniques/tools for slowing down and eventually reversing this degradation are needed. This paper promotes the identification and association of various tools for degraded arid ecosystems as strategies aimed at rangeland restoration/ rehabilitation. These strategies are founded on science-based evidence and experienced practitioners. For arid rangelands, the preference of applying an isolated rehabilitation technique may not halt degradation since the heterogeneity of the geomorphology, even at micro scale, and the landscape requires very often the use of different tools. For instance, direct seeding in degraded rangelands needs to be combined with soil scarification, when the crust dominates the soil surface, to reactivate the soil water retention and increase seedling emergence and germination possibilities. To achieve this goal, rehabilitation options identified for a specific degraded rangeland need to be holistically integrated with land degradation indicators in a manual-style decision support system for the long-term sustainable production of rangelands in arid environments.

Keywords. Dry areas – Land degradation – Sustainable rangeland management – Restoration.

Développer une boîte à outils pour la restauration / réhabilitation des parcours en milieu aride

Résumé. *Les parcours jouent un rôle écologique et économique très important et fournissent aux sociétés pastorales des produits et des services écosystémiques précieux. Dans de tels écosystèmes, une gestion efficace est nécessaire pour la croissance et la survie durables des plantes dans un contexte caractérisé par une aridité climatique et édaphique très accentué et soumis à une pression de pâturage élevée et non contrôlée. Par conséquent, il devient nécessaire de développer des techniques / outils rentables pour ralentir et éventuellement inverser cette dégradation. Cet article vise l'identification et la combinaison de divers outils pour les écosystèmes arides dégradés en tant que stratégies en vue de restaurer/réhabiliter les parcours naturels. Ces stratégies sont fondées sur des preuves scientifiques et des pratiques validées. Pour les parcours arides, le recours préférentiel à une technologie de réhabilitation isolée ne peut pas arrêter la dégradation car l'hétérogénéité de l'écosystème, même à petite échelle, nécessite très souvent la combinaison de plusieurs outils différents. Par exemple, la plantation d'arbustes fourragers sur des pentes relativement raides doit être associée à une technique de collection des eaux pluviales, pour tenir en compte du caractère torrentiel des en milieu aride. Pour atteindre cet objectif, les options de réhabilitation identifiées pour un parcours dégradé doivent être intégrées de manière holistique aux indicateurs de dégradation des terres dans un système d'aide à la décision sous la forme d'un référentiel technique pour assurer une gestion durable de parcours dans en milieux arides.*

Mots-clés. *Zones arides – Dégradation du sol – Gestion durable des parcours – Restauration.*

I – Introduction

The arid and semi-arid areas are estimated to cover 35% of the earth's land surface and are dominated by rangelands. They are major providers of critical ecosystem goods and services, including food, water, and livelihood sources for many of the world's poor (Milder *et al.,* 2010). Unfortu-

nately, these resources are on steady decline. For many decades national programs and development projects have attempted to reverse the trend of degradation, but in most cases the results were discouraging. Degradation which took place over hundreds of years cannot be reversed using quick fix solutions without considering the underlying causes. In fact, degradation is a result of poor management strategies interacting with other factors, such as climate change, which have continually increased the pressure on natural resources (Ouled Belgacem and Louhaichi, 2013). It is crucial to understand the causes of rangeland degradation and find solutions mobilizing a suite of available tools in a community-based participatory approach.

In this context, this toolbox has been developed to address rangeland rehabilitation at the landscape-level, taking into consideration the biophysical and socioeconomic linkages and trade-offs existing between the different land uses.

II – Sustainable Rangeland Management Practices

There are several sustainable rangeland management practices (SRMPs) that have been developed over the years. These SRMPs combine both indigenous knowledge and science-based interventions. Due to limited space (page number), in this paper we will only focus on key practices and approaches needed to ensure sustainability of rangeland restoration and rehabilitation.

1. Participatory rangeland governance

Sustainable rehabilitation of degraded rangelands that are dominated by collective and/or tribal ownership is a challenging task. The institutional arrangement to tackle this complex issue has been rather sectorial and fragmented. Earlier, the 'top–down' approach, which emphasizes technical solutions and neglects the social context, was the more common form of intervention. Therefore, in response to frequent failures of the top-down approach, efforts were deployed towards 'participatory development' as an alternative approach. National governments have been slow to adopt this participatory approach, but recent experiences suggest that integrated and participatory rangeland governance approaches may lead to more sustainable resource management. Rangeland governance can be defined as "local people's participation in managing the rangeland resources that they themselves use, in a sustainable manner" (Rist *et al.*, 2007). Such arrangement of development aims to organize people on a decentralized basis and to apply participatory tools in order to effectively empower local people (Nefzaoui *et al.*, 2014).

2. Water harvesting techniques

Water is an important resource in arid and semi-arid rangelands, but often it is wasted or allowed to erode the landscape. One way to address this is through simple, cost-effective water harvesting techniques (WHT). This practice has been used for thousands of years in arid and semi-arid regions of the world to supplement scarce water resources. In general, the interventions are used to increase soil moisture content, vegetation cover, and productivity. WHT can also control soil erosion and reduce the impact of drought. Experience of the last two decades provides increasing evidence that WHT can mitigate the increasing variability of rainfall. Among the widely used micro catchment WH techniques are contour ridges, semicircular and trapezoidal bunds and small runoff basins. When implementing WHT, field conditions such as slope of the terrain, soil properties, land use and land cover need to be assessed before choosing and constructing water harvesting structures. For large-scale implementation, a special plough can be designed to construct intermittent and continuous contour ridging (Oweis, 2016). In small areas and depending on the land characteristics, different manual constructing bunds can be implanted, includeing semi-circular bunds, stone bunds, earth basins and *Maskat*.

3. Soil surface scarification

Soil surface scarification is a technique that breaks up compacted surface soil to improve water infiltration. The main purposes of this practice are to facilitate germination and emergence of soil seeds and to create a favorable seedbed. This practice is commonly used to ensure a successful regeneration of the natural vegetation, either by sowing or by natural rehabilitation. It is recommended to use a chisel plow or a pitting machine to disturb the top crusty soil (upper 5-10 cm). This intervention should take place 1 to 2 weeks before the expected rainfall events (Gauthier, 2016).

4. Reseeding

Reseeding can be described as the process of introducing seeds of a new or fresh crop to replenish a depleted soil seed bank. Low-productive rangelands, which result in a lack of balance in forage production, must be rehabilitated by inexpensive methods such as reseeding to provide more and better-quality forage to support livestock and protect the soil. Reseeding has a potential of yielding high plant density at low costs and it is a cheap means for providing an adequate feed for livestock and a greater income from the grazing operation. Reseeding is appropriate for moderate to highly-degraded rangelands, where average annual rainfall is above 350 mm. It should be done only as part of a good rangeland management plan to improve both the reseeded area and the native range. Reseeding is necessary to increase nutritional value of forage, fill in bare spots and improve degraded rangelands after poor management. Successful reseeding will depend on; local climate, field characteristics, soil fertility, time of seeding, plant species selection, viability of seeds and the grazing management style.

5. Shrub transplantation

To alleviate the spread of rangeland degradation, planting shrubs provides a large amount of fodder for livestock, combats desertification, and plays a key role in natural resource conservation. The integration of shrubs has the potential to improve both the sustainability and profitability of land, thus improving the livelihoods of smallholder farmers. Shrubs well-adapted to conditions of individual planting sites should be selected. The choice of species will depend on the annual rainfall rate, soil, topography, runoff, and water harvesting potential of the site, and the likelihood of environmental stresses such as drought, salinity, and cold. Species selection is also guided by rangeland development objectives, such as fodder production, wood production, dune fixation, or erosion control. On the other hand, the limits of this rehabilitation method can be translated by the high cost related to the nursery and transplantation; the necessity of protecting the site for more than 2-3 years to ensure plants establishment and survival. The use of exotic shrubs has shown discouraging results in most cases either due to their ecological demands or to the difficulty of their management.

6. Grazing management

Grazing management is a tool to balance the capture of energy by the plants, the harvest of that energy by animals, and its conversion into a product that is marketable. Timing of grazing and growth rate of plants after grazing events are key factors in controlling the frequency, intensity and duration of grazing. These factors enhance soil stability, forage production, efficiency of forage use, and improve livestock production (Abu-Zanat *et al.,* 2005). Grazing is a natural method of land utilization to feed domestic livestock for converting grass and other forage into meat, milk and other products; it is the least expensive way to harvest forage. A proper grazing management should be holistic and using all the available resources with a pre-determined goal focusing on the fundamental ecological concepts/processes (Savory and Butterfield, 2016).

III – How does the toolbox work?

A toolbox is a guide that assists land managers and practitioners making diagnostic and taking proper measures to address causes of degradation. There is no “one size fits all”, as every ecological site has its own specificity. Past disturbances have profound impact on the current degradation status. For instance, direct seeding in degraded rangelands needs to be combined with soil scarification, when the crust dominates the soil surface, to reactivate the soil water retention and increase seedling emergence and germination possibilities (Figure 1).

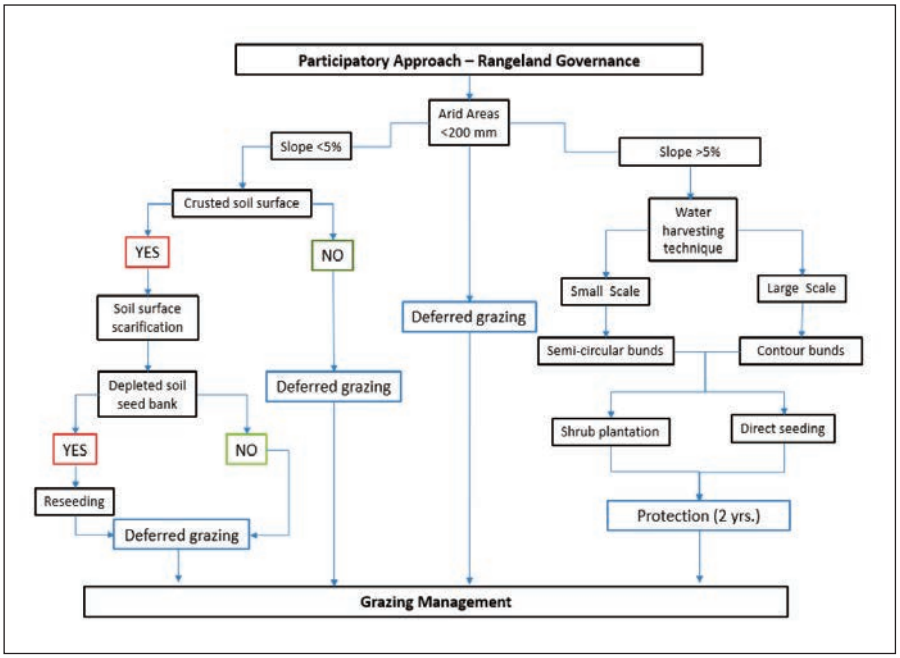

Fig. 1. Case study of the Jordanian Badia.

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Analysis of forage balances in the Djelfa region from 2001-2015. What is the place of pastoral and cultivated resources?

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Abstract. The degradation of pastoral resources has been accelerated as a result of the severe droughts in the 1970s and 1980s. In addition to that, the new land practices had a major impact resulting in a territorial dynamic recomposition. They have led to a scarcity of the available forage for rangelands by reducing their surface area and their productivity. This study aims to analyze the ability of agropastoralists to adapt to this uncertain context of forage availability and to maintain the level of animals' production. To do this, forage balances were computed during a period from 2001 to 2015 in the Djelfa region. The data studied came from the Department of Agricultural Statistics of the Ministry, the agricultural services of Djelfa and surveys of agropastors. Univariate descriptive statistical analysis showed a diversity of forage resources used to fulfil the nutritional requirements of animals. The share of pastoral supplies from home terroirs and pastures from transhumance contributes to 58% of animal needs. Thus,the pastoral resources remain decisive in the pastoralists' strategy for animal feeding. Nevertheless, the contribution of grown fooder and purchased feed is growing. It accounted for nearly 38%, of which 58% and 42% are concentrated feed purchased (mainly grain) and fodder grown (mainly barley in green), respectively. However, coefficients of variation ranging from 20% to 77% imply that both access to pasture and the contribution of forage resources remain irregular, uncertain and monetarised.

Keywords. Fodder – Balance – Djelfa – Diversity – Agropastoralists – Resources.

Analyse des bilans fourragers de la région de Djelfa de 2001-2015. Quelle place pour les ressources pastorales et cultivées ?

Résumé. *La dégradation des ressources pastorales s'est accélérée suite aux fortes sécheresses des années 1970/1980. En plus, les nouvelles pratiques foncières ont eu un impact majeur, entraînant une dynamique de recomposition territoriale. Elles ont conduit à une raréfaction du disponible fourrager des parcours par la diminution de leur surface et de leur productivité. Cette étude vise à analyser la capacité des agropasteurs à s'adapter à ce contexte d'incertitude pour maintenir le niveau de production des animaux. Pour ce faire, nous avons analysé les bilans fourragers durant une période allant de 2001 à 2015 dans la région de Djelfa. Les données étudiées provenaient du département des statistiques agricoles du Ministère, des services agricoles de Djelfa et d'enquêtes auprès des agropasteurs. Les analyses statistiques multidimensionnelles ont montré une diversité des ressources fourragères pour assurer les besoins nutritionnels des animaux. Les parcours des terroirs d'attache et les pâtures de transhumance contribuent à hauteur de 58 % aux besoins totaux des animaux. Ainsi, les ressources pastorales restent déterminantes dans la stratégie des éleveurs pour l'alimentation animale. Il s'avère néanmoins que la contribution des aliments cultivés et achetés est en augmentation. Elle représente près de 38 %, dont 58 % et 42 % sont respectivement des aliments concentrés achetés (surtout orge) et des fourrages cultivés (principalement de l'orge en vert). Cependant, les coefficients de variation allant de 20 % à 77 % impliquent que l'accès aux pâturages et la contribution des ressources fourragères restent irréguliers, incertains et monétarisés.*

Mots-clés. *Bilan – Fourrage – Djelfa – Diversités – Agropasteurs – Ressources.*

I – Introduction

In Algeria, livestock production remains a sector of considerable political, social and economic importance. Indeed, this sector represents nearly 51% of the Gross Domestic Product of Agriculture (GDP). The breeding of small ruminants, especially sheep, accounts for more than 50% of this GDP and is mainly concentrated in the steppe territories where many changes have been recorded: reduction in the surface area of rangelands, development of irrigated agriculture and high urbanization of rangelands. This has led to a context of high uncertainty which is increasing and accelerating the transformation of sheep production systems into steppe areas into agropastoralism and even more intensive forms of agriculture and livestock farming. Pastoralists / agropastoralists, regardless of their capacities, resources and capital production (assets), cannot escape the various factors of disruption (Hadeid *et al*., 2015; Kanoun, 2016; Hammouda *et al*., 2019). These developments, already reported in the 1970s, are now being accelerated and amplified. In addition to that, the different specialists in the natural, social and agricultural sciences confirm a regressive dynamics of the coverage vegetation and therefore the decrease of natural and pastoral feed resources for small ruminants (Nedjraoui, 2004; Aidoud *et al*., 2011; Bencherif, 2011; Ait-Alhayane, 2016). However, statistical data indicates that the sheep population not only remains stable but also shows a significant increase: estimated at 10 million heads in 1975-1977, it increased to over 27 million in 2018. Thus, steppe sheep farming is at the heart of a striking paradoxical evolution.

The ambition of this study is to qualify the different forage resources used (nature, origin and contribution) to feed the steppe sheep herds in the Djelfa region. For this purpose, we exploited and interpreted data from state institutions (Djelfa Agricultural Services, Department of Agricultural Statistics of the Ministry and High Commissioner for Steppe Development) and individual interviews with sheep farmers (sedentary, semi-transhumant and transhumant). Therefore, we were able to work on the hypothesis that animal feed comes largely from grazing spontaneous forage resources, despite an increase in cultivated feed.

II – Material and method

The choice of the region of *Djelfa*-Algeria was mainly dictated by the nature of our theme, which includes a study area where the population is still attached to livestock activities, particularly sheep, and is highly dependent on them. Indeed, the *Djelfa* region has more than 3.5 million heads (14% of the national livestock population) and is the leading region in the country. Converted into LU, ts livestock is essentially composed of sheep, representing 72% of the total number of livestock.

To analyze the dynamics of forage resource use, we put emphasis both on institutional databases and on livestock farm surveys. So, the first step of our work is based on statistics from the various institutions responsible for collecting data on agricultural and ecological activities, particularly those that allow us to analyze the evolution in the nature and the contribution of feed resources used (natural range areas, cultivated fodder, subsidized food, forage resource yields, animal requirements). Using the work of INRA (1988), conversion coefficients were selected and assigned to each forage resource expressing its nutritional value in forage units (FU). In addition, to calculate the nutritional needs of the livestock, we used the “livestock unit” (LU) in order to account for the different species and animal categories studied (sheep, goats, cattle, horses, camels, donkeys). The values used are those of Moskal (1983). Fodder production (spontaneous and cultivated), was estimated on the basis of the yield evaluation using the quadrate-point method carried out by the “evaluation unit of the Djelfa Agricultural Directorate” and the “High Commission for the Development of the Steppe” (DSA, 2018 and HCDS, 2010). The second step consisted of single-run surveys of sheep farmers (30 agro-pastoralists) based on a semi-directive questionnaire focusing on the following aspects: nature, origin, contribution of forage resources and level of feed self-sufficiency. The data obtained were subjected to statistical descriptive univariate analyses.

Our approach is based on systemic and constructive approaches. Indeed, these approaches, which make it possible to integrate factors of different origins, are recognized as essential to account for the relationships between livestock production methods and their natural and socio-economic environment (Gibon, 2005; Lambin, 2005).

III – Results and discussion

1. Contribution of natural forage resources: uncertainty and irregularity

The fodder intake balances (in forage units: FU), established in the Djelfa region during the period 2001-2015, show that the contribution of the various local fodder resources is low and covers on average 45%±14 of the livestock's feed requirements (Table 1). The coefficient of variation of 31% shows that the contribution is irregular. In addition to the impact of climate change hazards, this irregularity is mainly due to poor governance of land tenure systems applicable to steppe rangelands, which has led to severe degradation of pastoral resources (Kanoun, 2016; Hammouda *et al*., 2019). Indeed, decentralization has strengthened the capacities and powers of some local actors to extend their control (land grabbing) over their agricultural and livestock practices, which is incompatible with the preservation of natural resources (Bessaoud, 2006, Bencherif, 2011 and Kanoun *et al*., 2013). On average, the local rangelands account for 22%±9 of total feed resources. The coefficient of variation of 42% indicates the level of uncertainty of this contribution. Rangeland rehabilitation programmes do not seem to yield results in terms of contribution of this forage resource to herbivores' intake. Indeed, the contribution of the restored rangelands (Atriplex-based pastoral plantations and enclosed grazing areas) is below the desired potential. This forage source covers only 1% to 5% of the total requirements of the animals. In addition to the deterioration of climatic conditions, the management practices implemented and the lack of interest of livestock farmers for environmental issues are the determining factors explaining the low pastoral productivity and the development of plant species that are less appreciated by the animal (Guesmi, 2016). The study carried out by the HCDS (2010) indicates a very high level of grazing land degradation, particularly in the western and central steppe. Even with the contribution of transhumance, grazing cannot meet the total needs of the livestock. Such contribution varies between 25% and 55%. However, its coefficient of variation of 20% suggests a more stable contribution than other feed resources. The strengthening of physical capital (development of motorization) explains this ability of herders to improve their self-sufficiency through transhumance (Kanoun, 2016). The results of the survey with transhumant herders showed that the amplitude of transhumance and the number of farmers resorting to new pastoral areas have increased significantly over the past two decades. Finally, grazed resources remain a determining factor in livestock farmers' feeding strategies, covering on average 58% of animal requirements.

Table 1. Contribution of the various forage resources to the feed requirements of livestock (%)

Types of contribution	Minimum	Maximum	Average	SDn	CV
Transhumance[1]	25	55	34	6	20
Local rangeland	13	45	22	9	42
Local fodder contribution[2]	28	82	45	14	31

[1]Estimated transhumance inputs: transhumant livestock*20UF/month*duration of mobility (5 months/year).
[2]Local fodder contribution: cultivated and spontaneous resources + transhumance contribution + subsidized food.

2. Place of cultivated resources: still insufficient to reduce the deficit

Table 2 illustrates the diversity of cultivated resources and the uncertain contribution of cultivated forage production to compensate for the inadequacy of spontaneous pasture. All the coefficients of variation of the different forage crops are very high, i.e. the production of these resources is subject to a multitude of uncertainties, particularly social, economic and natural. These indicators reflect the irregularity of the cultivated forage supply in recent years. Moreover, the contribution of this food category is around 16% on average and varies between 3% and 32%. This contribution is mainly ensured by the production of irrigated green barley (with sprinkling and raw spreading), which represents nearly 60% of the total production of cultivated fodder. Alfalfa production has the highest coefficient of variation, both in terms of production (122%) and in terms of surface area (161%). In recent years, the region has seen a significant increase in the area under Alfalfa cultivation. This growing interest in this animal feed source is mainly due to the development of groundwater resource mobilization for agricultural irrigation. The results of our survey among agropastoralists showed that nearly 42% of the breeders have drilled deep wells. On the other hand, the analysis also reveals that the area cultivated with Alfalfa varies between 0.5 hectares and 3 hectares for 45% of the breeders surveyed. At a local level, this forage crop has shown rapid adaptation and recovery after first cut (Chaabena *et al*., 2004). According to these authors, the number of cuts/year varies from 6 to 8. In addition to that, it is exploited in green or hay form for most of the year (March to November). The incentives in our study area encourage the adoption of alfalfa (*Medicago sativa*) by local livestock population. On the other hand, to ensure the sustainable development of livestock farming activities, water resources need to be regulated and it is better to choose Alfalfa cultivars that do not require significant irrigation. Another characteristic of steppe sheep farming is the frequent membership of breeders in a professional organization, in particular the Chamber of Agriculture of Djelfa. This membership allows them to benefit from concentrated feed, in the form of granular barley. However, the results showed that the contribution of this subsidized distribution is low: 5% of total feed.

Table 2. Cultivated feed production (in M FU) in the Djelfa region

Type of resources	Minimum	Maximum	Average	SD	CV	Share in forage production
Green alfalfa	0	2.8	0.9	1.1	122%	0.6%
Oats grain	0	0.6	0.1	0.2	113%	0.1%
Disaster-affected cereals	0	3.5	0.9	1	104%	0.6%
Straw	0.6	23	8.8	8.4	95%	5.9%
Subsidized barley	0	85	41.6	34.7	83%	
Stubble	1.2	21.1	8.9	6.8	76%	5.9%
Green Sorghum	0.1	0.5	0.2	0.1	65%	2.2%
Oat hay	0	7.5	3.8	2.4	64%	2.5%
Barley grain	2.1	65.3	33.4	21.1	63%	22.3%
Green barley irrigated spraying	7.5	85	38.7	23.8	61%	25.9%
Green barley irrigated spreading	12	120	50.6	29.3	58%	33.8%

3. Difficulty to reach feed self-sufficiency

Our analysis identifies forage surpluses only for the years 2009 and 2010. This production context is explained by seasonal climatic conditions strongly favorable to the production of pastoral and spontaneous resources (Kanoun *et al*., 2015). On average, over the period studied, the forage deficit was estimated to 20% and ranged from 21% to 41% (Fig. 1). The analysis of the information collected from livestock breeders confirms the irregularity of the availability of food resources. Indeed, 95% of livestock farmers testify as to their inability to achieve feed self-sufficiency with spontaneous and cultivated resources.

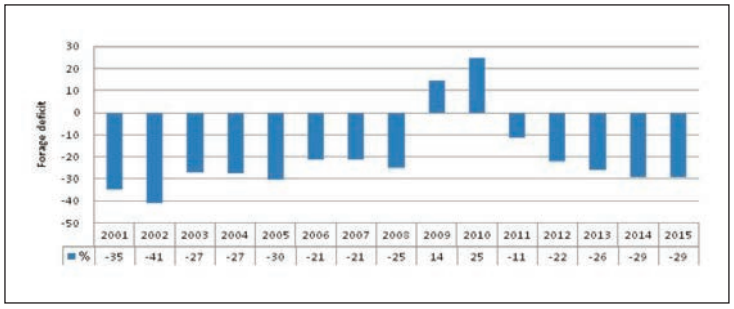

Fig. 1. Evolution of the fodder deficit in the Djelfa region.

Moreover, the coefficients of variation of the various contributions, which vary between 20% and 77%, imply that these feed resources remain uncertain. However, the absence of feed self-sufficiency, causing an increase in purchased does not seem to handicap increases in animal numbers and, consequently, a further increase in their total feed requirements (Fig. 2).

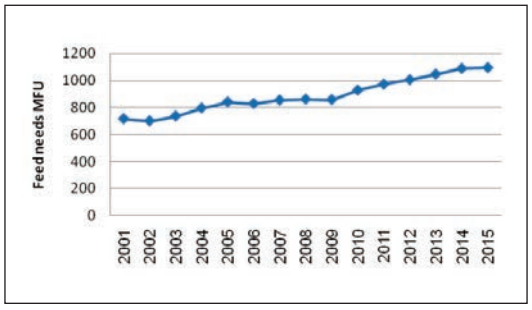

Fig. 2. Evolution of food needs of Djelfa animals.

VI – Conclusion

The challenge for livestock farmers in the Algerian steppe is the sustainability of their livestock, which must evolve in highly changing contexts characterized by increasing climatic, agronomic and socio-territorial hazards. This study showed that livestock farmers have adapted to adversity by adopting strategies based on the diversification of forage resources to increase their feed self-sufficiency. However, these strategies involve risks associated with the lack of good governance of rangeland and cropland. Finally, from a methodological point of view, the work carried out in this study leads us to continue our thinking about indicators that would allow us to better quantify or evaluate, feed availability according to seasons, livestock producers' means, livestock systems, etc.

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Autonomy and herbaceous forage in goat farming of western France. First results of a sociological survey

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Abstract. Our communication is based on the results of a multidisciplinary research (PSDR FLECHE – Fromages et Laits issus d'Élevages de Chèvres conduites avec de l'Herbe – 2016-2020) which aims to study the potential of grass utilization in goat systems, with the dual objective of strengthening the economic resilience of farms and the social image of the dairy goat sector of Western France. The latter currently represents almost half of the national goat population and 58% of the goat milk supplied in France. The sociological aspect of the research concerns the representations, value systems, interests and constraint systems (technical, economic, etc.) that guide the practices of all stakeholders in the sector: farmers, upstream and downstream actors. The objective of this approach is to analyse, at all levels of the value chain, the incentives and obstacles to a possible transition to grass-based feeding systems. Based on 76 semi-directive interviews, this paper presents the first results of this survey by showing how contextual elements (socio-economic, professional, etc.) impact farmers' choices of practices. While, in principle, the whole goat sector seems to be converging towards an agro-ecological transition that ensures its sustainability, in practice, each stakeholder is confronted with a system of constraints that limits actual developments. The articulation of these obstacles seems to lead to a kind of inertia, which prevents the adoption of practices that are nevertheless perceived as recommendable by most stakeholders.

Keywords. Autonomy – Herbaceous forage – Goat – Sociology.

Autonomie et fourrages herbagers dans les élevages caprins de l'Ouest de la France. Premiers résultats d'une enquête sociologique

Résumé. *Notre communication s'inscrit dans le cadre d'une recherche pluridisciplinaire (Programme PSDR – FLECHE – Fromages et Laits issus d'Élevages de Chèvres conduites avec de l'Herbe – 2016-2020) qui vise à étudier le potentiel de valorisation de l'herbe dans les systèmes caprins, dans le double objectif de renforcer la résilience économique des exploitations et l'image sociale des filières caprines laitières de l'Ouest de la France. Ces dernières représentent actuellement près de la moitié de l'effectif national de chèvres et 58% du lait livré en France. Le volet sociologique de la recherche porte sur les représentations, les systèmes de valeurs, les intérêts et les systèmes de contraintes (techniques, économiques, etc.) qui orientent les pratiques de l'ensemble des acteurs de la filière : éleveurs, acteurs de l'amont et de l'aval. L'objectif de cette démarche est d'analyser, à tous les niveaux de la filière, les incitations et les freins à une éventuelle transition vers des systèmes alimentaires plus herbagers. A partir de 76 entretiens semi-directifs, ce papier présente les premiers résultats de cette enquête en montrant, notamment, comment les éléments contextuels (socio-économiques, professionnels, etc.) impactent les choix de pratiques des exploitants agricoles. Si, en principe, l'ensemble de la filière caprine semble converger vers une transition agroécologique qui en assure la durabilité, dans la pratique, chacun de ses acteurs est confronté à un univers de contraintes qui limitent les évolutions effectives. L'articulation des freins relevant des différents maillons de la filière, semble ainsi déboucher sur une sorte d'inertie, qui empêche l'adoption de pratiques pourtant perçues comme souhaitables par la plupart des acteurs.*

Mots-clés. *Autonomie – Fourrages herbagers – Capris – Sociologie.*

I – Introduction

In a context characterized by renewed attention to environmental issues and lower prices for agricultural products (Bourgeois and Demotes-Mainard, 2000), agricultural sectors are promoting the adoption of production systems that are both more sustainable and less costly, thanks to the reduction of inputs (Lécole and Thoyer, 2017). Several authors suggest the use of agro-ecology to improve the self-sufficiency and sustainability of livestock farms (Altieri, 2002; Dumont *et al*., 2013; Dumont *et al*., 2018). With regard to goat systems, the use of grass, when available, can be an asset to strengthen self-sufficiency, control production costs and secure systems against economic hazards (Peyraud *et al*., 2014). In addition, the utilization of grass is likely to bring a positive image to goat cheese, and promote the preservation of biodiversity and landscapes as well. While recent research on dairy cattle farms has helped to identify the obstacles to changes towards grass-based feeding systems (Peyraud *et al*., 2010; Le Rohellec and Lusson, 2013), there are still many obstacles to identify and overcome in order to develop these feeding systems in goat farms. In this context, the PSDR FLECHE project (Fromages et Laits issus d'Élevages de Chèvres conduits à l'Herbe) aims to study the technical, economic and social incentives and obstacles to the adoption of grass-based feeding systems in goat farms of western France, which represent almost half of the national goat population and 58% of the milk supply (IDELE, 2018). It also aims to provide scientific and technical references in order to facilitate this transition. This article presents a sociological analysis of the motivations and obstacles to the adoption of these feeding systems, based on a survey conducted among the actors of the dairy goat sector.

II – Methodology

The survey is based on semi-directive interviews conducted by the authors and 46 engineering and MSc students in "Science and Animal Production" (Agrocampus Ouest), specifically trained in the methodology of interview surveys. The interviews were conducted between October 2016 and November 2017 with the stakeholders of the goat sectors of the Poitou-Charentes, Pays de la Loire and Brittany regions. In total, we conducted 76 interviews with 34 farmers (intensive; extensive with pasture-based system); 37 upstream and downstream stakeholders (11 from processing companies; 6 from technical consulting organizations; 6 from cooperatives and service companies; 5 from agricultural training schools; 3 from health management institutions; 1 from a control authority; 1 from a slaughterhouse); 3 representatives of credit and rural economy institutions; 2 representatives of local authorities. The sample was not intended to be representative of the whole sector, but to reflect the diversity of stakeholders and livestock farming systems. The transcribed interviews were subject to a cross-analysis of the discourses, in order to highlight the dispositions systems, representations systems and constraints systems that can influence the strategies and choices of practices for the different actors in the sector.

III – Incentives and obstacles to the development of grass-based feeding systems in the goat sector

All stakeholders shared two concerns. The first was the medium– and long-term sustainability of goat systems, which are affected by recurrent economic crises, among other things, because of their low level of feed self-sufficiency (Bossis *et al*., 2014). The second concern was the risk of a deterioration of the social image of the sector, in the event that the media reveal the intensive production systems that predominate in goat farms. These concerns have led certain stakeholders to question the sustainability of the current production systems, as also indicated by the emergence of a growing number of research programmes on this subject (FLECHE; REDCap; CAPHerb projects). Several actors (representatives of trade unions and producer groups, technical advisory companies, pro-

cessing companies, agricultural training institutions and some of the farmers) agreed that a transition to grass-based systems would strengthen the resilience of goat farms on the one hand and on the other hand would bring farming practices closer to consumers' expectations. It may be added that, in line with consolidated national trends (Lécole and Thoyer, 2017), the promotion of an agro-ecological transition is also perceived as desirable by local and regional authorities.

With a favourable political context and many actors increasingly concerned by these issues, the conditions would seem to be set for the transition to take place. However, the effective evolution of feeding systems is hampered by a series of constraints at all levels of the value chain.

Milk processing companies are sensitive to issues related to the low resilience of farms (which may threaten the supply of milk) and to the possible deterioration of the social image of the sector (which may threaten the sale of goat products). However, they are also concerned that changes in management systems could lead to a reduction of total milk production, as well as difficulties in the logistical organisation of milk collection (in the event of a double collection); the management of health risks (risk of listeria for raw milk cheeses); the management of fluctuations in milk production (greater in grass-based systems); and the management of variations in milk composition (variations in fat/protein ratios; increased presence of somatic cells). Thus, there is a tension between the favourable perception of a possible transition to grass-based systems and the tendency to maintain current systems that are easier to control.

On their part, technical advisory companies are also sensitive to previously mentioned issues, because their existence is closely linked to the sustainability of the whole sector. Nevertheless, the technicians interviewed felt they did not have the necessary skills to support a transition to grass-based feeding systems. This could be explained by the fact that grassland cultivation is rarely covered in higher agricultural education institutions, where "Animal Production" curricula focus on zootechnical aspects and "Plant Production" curricula focus on field crops.

Training in grass-based feeding systems is also practically absent from agricultural secondary and professional curricula in the regions concerned by our survey. Indeed, while the teachers and technicians from the agricultural training institutions (EPLEFPA) surveyed say they are in favour of promoting grass-based feeding systems, the educational farms of these institutions are faced with a shortage of staff. As a result, students are only exposed to systems that are less burdensome in terms of workload (distribution of corn silage and commercial concentrates). This lack of training seems to be one of the obstacles to the evolution of farmers' practices.

From farmers' point of view, other obstacles stem from the perception that the adoption of a grass-based feeding system implies considerable economic investments (acquisition of land, adaptation of buildings, purchase of suitable machinery, etc.); increased difficulties in managing health risks (parasitism, listeria, acidosis, etc.); a permanent adjustment of the feed ration (due to seasonal variations in the nutritional value of the grass) and fluctuations in milk production (qualitative and quantitative).

However, it must be noted that the main obstacle to the dissemination of grassland systems is the fear of an increased workload due to : grassland planning and management, development of fences and monitoring of animals at pasture; daily collection of grass for green feeding; time spent travelling between livestock buildings and the fields and difficulties in automating the distribution of feed. It is noteworthy that farms that have adopted such systems tend to be smaller (in terms of Utilised Agricultural Area and livestock numbers) and more specialised than the average farm from the sample studied.

Finally, it seems that the dissemination of grass-based feeding systems could also be hindered by difficulties in accessing credit. The representatives of the credit institutions we interviewed are reluctant to support investment towards these systems. Such reluctance is attributed to the absence of consolidated technical references. However, this hypothesis would require verification with a larger number of credit institutions.

IV – Conclusion

While, in principle, most stakeholders in the goat sector perceive the value of grass as an asset to strengthen the resilience of farms, in practice, each of them is confronted with a system of constraints that limit the effective dissemination of grass-based feeding systems. The articulation of obstacles at different levels of the goat sector seems to lead to a kind of inertia, which prevents the adoption of practices that are nevertheless perceived as desirable by most actors. This inertia is so strong that it seems to have transformative effects on the dispositions internalized by individuals. Thus, after an agricultural training, internship experiences, interactions with technicians, and experience of the reluctance of credit institutions and of the specific difficulties of goat farming, some young farmers who initially intended to create an extensive and pasture-based farm, have finally opted for a conventional feed management.

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Different forms of Crop-Livestock Integration. Analysis in the South of France

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Abstract. Reconnecting crops and livestock is a way of contributing to agro-ecological transitions in production systems and territories. This is a particularly important challenge in the Mediterranean area because of the marked specialization of territories, with cash crops in lowland areas and on the coast, while livestock farming is concentrated in inland regions, which are often in decline. There are various forms of Crop-Livestock Integration (CLI). Based on a few specific examples, we present various forms of CLI (reconnecting the crop system and the livestock system on the farm; local-level arrangements between neighbours; partnerships between winegrowers or orchard farmers and breeders; cooperation between stakeholders on a regional scale, and so on). We will study the conditions for their implementation, the changes brought in the activities, the potential performance and the prospects offered by these forms of CLI for the development of livestock systems and territories in the Mediterranean area.

Keywords. Mixed farming – Crop – Livestock – Integration – Reconnection – Transition – Cooperation – Arrangements.

Différentes formes d'intégration agriculture-élevage. Analyse dans le Sud de la France

***Résumé**. Reconnecter cultures et élevage est un levier pour favoriser des transitions agro écologiques à l'échelle des systèmes de production et des territoires. En zone méditerranéenne, cet enjeu est particulièrement important du fait de la spécialisation marquée des territoires : cultures de vente en plaine et en littoral, élevage dans les arrières pays, souvent en déprise. L'Intégration Culture-Elevage (ICE) peut prendre différentes formes. A partir d'exemples concrets, nous présenterons diverses formes d'ICE, (remise en connexion du système de culture et du système d'élevage dans l'exploitation ; organisation à l'échelle locale entre voisins ; collaboration entre viticulteurs ou arboriculteurs et éleveurs ; coopération entre acteurs à l'échelle régionale). Nous étudierions les conditions de leur mise en œuvre, les changements induits dans les activités concernées, les performances potentielles et les perspectives offertes par ces formes d'ICE pour le développement de l'élevage et des territoires en zone méditerranéenne.*

***Mots-clés.** Agriculture mixte – Culture – Élevage – Intégration – Reconnexion – Transition – Coopération – Arrangements.*

I – Introduction

The agricultural modernization policies implemented in France since the 1960s have resulted in the specialization or even the disconnection of arable and livestock farming both at production systems and territorial scales. In the French Mediterranean area, the segmentation of space is particularly marked: we find intensive monoculture in lowlands and largely pastoral livestock farming in the foothill areas in decline. In this kind of context, Crop-Livestock Integration (CLI) is one of the key approaches for making the agro-ecological transitions and reinforcing the sustainability of activities in the territories (Mischler *et al*., 2019). However, CLI can prove difficult to implement because the sectors and advisory bodies have become specialized and due to a number of socio-technical barriers (Geels, 2007). Now is a good time to design LCI projects. Society's re-evaluation of intensive agriculture, the evolution of food systems, the increasing focus on environmental issues and the climatic emergency all raise questions about the future direction of arable and livestock farming.

A few pioneering initiatives are gradually emerging. Some involve a single farm and farmer, while others involve several farmers pooling their land. There are also mutually agreed arrangements between, for example, a mountain livestock farmer and a lowland farmer and, more rarely, projects rolled out on a regional scale. In this document, we analyse four situations where arable and livestock farming have been reconnected in the South of France: two at farm level, involving only crop growers and livestock farmers, and two at the scale of a natural park area or a municipality, involving a diversity of stakeholders. We compare these contrasting situations to identify the lessons to be learned about emergence conditions of CLI, to identify limitations to CLI, and to discuss the contribution of CLI to the agro-ecological transitions.

II – Original ways of reconnecting crop and livestock farming

1. A small herd grazing in an orchard

Seeking to reduce chemical treatments in their orchards, some farmers have acquired a small flock to control certain pests and diseases such as voles, codling moth and scab (Dufils, 2017; Rey and Coulombel, 2008). A first management strategy consists in a post-cropping grazing of the orchard to consume and reduce as far as possible fallen fruit and leaves, the latter being potential sources of inoculum. The flock leaves the orchard at the onset of the budding period. In this case, the farmer has at his disposal other foraging areas : grasslands, summer pastures, rangelands to feed the flock during spring and summer. A second management strategy consist in maintaining the flock in the orchard for as long as possible. Grazing can occur all year round, except in periods of fruit harvesting or lambing. Such strategy offers more opportunities and flexibility to synchronize the timing of grazing with pathogens cycles, thus increasing the impact on pests and diseases.

The presence of the herd is an additional factor to be considered in terms of type of work to be done in the orchard. The additional work introduced by livestock farming includes managing grass resources, developing mobile pens for rotational grazing under the trees, observing animals and sward to see when grass resources become insufficient and a change of paddock is required, and protecting tree bark from damage. Livestock farming also implies more time constraints, a different health management and different regulations. It also calls on different networks (e.g. veterinarians, sheep shearers, slaughterhouses, etc.) to be added to the farmer's usual set of contacts. The integration of livestock in the orchard will largely depend on what services the farmer expects and on his interest in livestock farming. It will also be closely linked to his ability to develop an integrated production system and acquire new skills.

2. Reverse transhumance based on mutual agreement between a winegrower and a livestock farmer

The agricultural systems involved – viticulture on large estates in the *Var*, and sheep farming for meat in the southern Alps – have undergone significant changes in recent decades (Garde *et al.,* 2014, Dupré *et al*., 2017). In viticulture, there is a renewed interest in winter grazing of sheep in vineyards, prompted by the growth of certified organic wine markets and a marketing approach aiming to promote winegrowing as integrated with other activities in rural areas. The aim of CLI here is to minimize weed growth between vine rows using grazing rather than herbicides, while giving wine a pastoral image associated with 'natural values'.

In sheep farming, there has been a sharp increase in herd sizes in the mountain areas of the Southern Alps, caused by economies of scale and public incentives since the 1990s. However, on some farms, this has been limited by the capacity to build up sufficient forage stocks for winter feeding. To overcome this, livestock farmers in the mountains bring their flocks down to the lowland coastal areas in winter, to graze shrubland and forest areas. They often work hand-in-hand with public authorities to reduce fire risk.

This context favours the reactivation of a traditional winter transhumance almost abandoned during the second part of the 20 th century. In fact, the lowland areas grazed by livestock are close to the wine estates, which has led to the development of winter grazing among the vines, on the basis of mutual agreements between the two types of farmer. These agreements require (i) the provision of large areas of pastureland, adapted to the size of the flocks; (ii) grazing in small paddocks, developed using mobile pens which can be easily removed in case agricultural operations are carried out in the vineyard. Such CLO involves just two parties: the manager of the vineyard estate and the livestock farmer, in a relationship of subordination. In fact, the constraints of livestock farming must not hinder the flexibility required for the management of the vineyard. Large flocks with limited production objectives are the best type of partner for this kind of CLI.

3. Synergies between arable farming and livestock breeding at the level of a regional natural park

Animals and crops have been farmed together in various ways throughout agricultural history. Today, as agriculture evolves towards more sustainable production systems, orchard farmers are choosing to let ewes graze among their fruit trees. As in our first example, their main aim is to manage grass cover and to improve the control of certain pests and diseases while reducing chemical inputs such as plant protection products or fertilizers. In the *Alpilles* Massif, some farmers joined up with '*herbassier*'[1] shepherds, in order to graze the large sheep flocks in dense fruit-farming areas, from the end of the harvest until bud emergence the following spring. This informal arrangement benefits both parties, providing access to grass resources for the herd and maintenance of the grass cover in the orchard (Ducourtieux *et al*., 2012).

With its role in territorial management, the *Alpilles* Regional Natural Park is trying to capitalize on this practice to encourage new connections between crop farmers and livestock breeders as part of a multi-partnership project, with the aim of reducing agricultural inputs to protect the area's rich avifauna. This initiative has a clear sociological objective: to bring together stakeholders from different sectors who rarely mix otherwise. However, one of the challenges will be to coordinate CLI with other activities and stakeholders (elected officials, hunters, walkers, etc.) over the long term, while maximizing synergies with livestock breeders already present in the territory, in forest areas or in annual crop-growing areas.

4. Synergies between mountain areas and low-lying plains on a regional scale

In the framework of a development project (financed by a program launched by the Ministry of Agriculture in 2012 to support collective actions encouraging agro-ecological transitions), local officials from a coastal town in the South of France (*Claira*) and livestock farmers from the *Pyrenees* foothills (*Canigou*) worked together to convert peri-urban agricultural wastelands into forage crops. Together, they pursued two objectives : promote a diversified land use in the coastal area and increase feed self-sufficiency of livestock farms by producing hay and cereals, which is not possible in mountain areas (Napoleone *et al.,* 2019; pleinchamp.com, 2017).

The town recruited a land coordinator to convince landowners to lease out their fallow land free-of-charge (one or five-year lease). Five livestock farmers set up a business together (with SARL limited liability status) and worked together to cultivate the land. The land coordinator oversaw the initiative to ensure consistency between the actions carried out by the various parties. Other stake-

1. A 'herbassier' is a sheep farmer with no land of their own, who moves their herd from the coast to the mountains following the various levels of vegetation.

holders (hunters, other farmers, residents, etc.) were involved in the project in a formal or informal way. Over five years, the five farmers cultivated a total 100 ha and are now fully self-sufficient. The spatial distribution of cultivated land within the municipality is discussed and agreed on by the various stakeholders. It includes cultivated areas designed to conserve biodiversity (10% of the surface area, i.e. 10 ha, distributed across the territory), which location is discussed with hunters and hunting and wildlife associations. The scheme has built real social dynamics in the municipality, where people are happy with the project. It has reshaped the urban fringes and represents a support for small-scale mountain livestock farmers.

This system involves various parties. Starting with private property (the fallow land), a resource that benefits the community on the territorial scale is gradually developed, enabling (i) agro-ecological dynamics in the lowland area (e.g. cultivating legume crops), and (ii) support for livestock farming activity in the foothills.

III – Discussion

1. A traditional practice that is being revisited

Farming practices connecting crop and livestock farming are developing in southern France. There is a wide potential of expansion of CLI in the future. As an example, in the *Var* department, 35000 hectares of vineyards and olive orchards are potentially available for grazing, that is to say 7 millions of grazing days for ewes (estimation from the Vitipasto project). In the *Pyrenées Orientales* department, the Chamber of Agriculture estimate that 10 000 hectares of abandoned farmland are available and that cropping one tenth of them could restore the feed self-sufficiency of all the pastoral systems in the area.

2. Conditions for emergence

Many farmers start to question their production methods and seek new ways of reducing inputs, which is in line with consumer expectations about farming practices and the quality of agricultural products. These situations arise from a sense of dissatisfaction or a need to shift towards a more ecological approach. They also occur when stakeholders involved in different activities come together. Even though they may have different concerns, they are all interested in the benefits of CLI and in the synergies which may be activated by their cooperation.

3. Considering a CLI situation over the long term

Livestock is sometimes seen by farmers or other stakeholders in the lowland areas as the key to a reduction in the number of chemical treatments or machine operations. They can therefore focus on the constraints and objectives specific to their farm or territory. However, letting a herd graze on a particular type of plot at a particular time, or growing legume crops in lowland areas must also be compatible with the work involved in livestock farming and the organization of the livestock system. If the transitions are to be sustainable and viable in the long term, grazing must not be reduced to the provision of an 'environmental service'. CLI, which reconnects two specific functions – crop and livestock production – must be considered as a complex system, with its own rules and constraints. In any case, knowledge must be acquired and operations (livestock farming and cultivation) need to be coordinated on the basis of mutual understanding between stakeholders.

4. Private property and common interest

When the debate occurs at a territorial level (e.g. regional natural park, municipality), besides economic aspects (such as reducing inputs or increasing the value of market goods) and private property, CLI raises the question of incorporating livestock through a mechanism that generates a common good. We can certainly consider territory, landscape and environment as common goods. Livestock farmers manage a set of paddocks (usually private) scattered within a territory, thus making a beneficial contribution to the community at an intermediate stage between private and public goods (Ostrom, 2010). In this context of a declared common good, governance issues arise, involving a diversity of stakeholders, and the implementation of multi-level coordination.

5. Livestock farming generates agro-ecological dynamics in areas of intensive cultivation

Regardless of the scale considered, livestock farming helps to set the agro-ecological transition into motion. At farm level, grazing reduces chemical treatments and other operations in orchards and vineyards. At a large territory scale, it enables crop diversification, for example with the introduction of legumes or permanent grasslands, improving the fertility of soils degraded by decades of intensive monoculture (e. g. vines).

IV – Conclusion

We can imagine a variety of ways of reconnecting crop and livestock farming. CLI is clearly of interest in the Mediterranean area. Despite the specialization of territories and activities, it offers some valuable opportunities to increase feed self-sufficiency for herds, reduce chemical inputs such as plant protection products or herbicides for crops, and trigger agro-ecological dynamics within territories. However, there is no turnkey model. Although certain CLI (e.g. winter transhumance) are based on traditional methods, all these systems are somehow pioneer. The various parties involved therefore need to embark on a step-by-step learning process to secure the sustainability of these new forms of arable and livestock farming.

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Bells in small ruminant farming in Mediterranean pastures

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Abstract. Animals' bells have facilitated the work of livestock farmers around the Mediterranean since ancient times, both in mountain pastures and in lowland areas. The purpose of this study was to record the viewpoint of small ruminant farmers about the significance the bells have for them nowadays. The empirical study was conducted with 29 small ruminant farmers in Greece, by using the semi-structured interview technique. The results showed that bells help shepherds locate their flock or even individual animals within the flock at a considerable distance, thus saving time and cost. Bells also help them to check whether animals graze serenely or are exposed to external dangers. In normal grazing conditions, the soft tinkling of the bells neutralize external noises, thus promoting gentle grazing and enhancing the animals' ability to locate one another. At the same time, as far as small ruminant farmers are concerned, bells could be a source of pride and social acceptance by fellow farmers. Bells also contribute to the shepherd's enjoyment as they seek to use appropriate combinations of bells that deliver harmonious and pleasant sounds. Although nowadays there are much more modern means for locating animals and for farmers' entertainment, bells continue to play an important role for the majority of Greek transhumance farmers.

Keywords. Bells – Small ruminant farming – Pasture – Mediterranean.

Sonnailles dans l'élevage de petits ruminants dans les pâturages méditerranéens

Résumé. *Les sonnailles des animaux ont facilité le travail des éleveurs autour de la Méditerranée, tant dans les alpages que dans les pâturage de plaine, et ce depuis l'antiquité. Le but de cette étude était d'enregistrer les points de vue des éleveurs de petits ruminants sur l'importance que les sonnailles ont pour eux aujourd'hui. Une enquête a été réalisée chez 29 éleveurs de petits ruminants en Grèce, en utilisant la technique de l'entretien semi-structuré. Selon les éleveurs, les sonnailles aident le berger à localiser son troupeau ou même des animaux précis au sein du troupeau et ce à une distance considérable, économisant ainsi du temps et de l'argent. Ils l'aident également à vérifier si les animaux paissent sereinement ou s'ils sont exposés à des dangers extérieurs. Dans des conditions de pâturage normales, le léger tintement des sonnailles neutralise les bruits extérieurs, favorisant ainsi un pâturage en douceur et renforçant la capacité des animaux à se localiser. Dans le même temps, pour les éleveurs de petits ruminants, les sonnailles pourraient être une source de fierté et d'acceptation sociale de la part des agriculteurs. Les sonnailles contribuent également au plaisir des bergers, qui cherchent à utiliser les combinaisons appropriées de sonnailles pour produire des sons harmonieux et agréables. Bien qu'il existe aujourd'hui des moyens beaucoup plus modernes de localisation des animaux (GPS, par exemple) et de divertissement des agriculteurs, les sonnailles continuent de jouer un rôle important pour la majorité des agriculteurs transhumants en Grèce.*

Mots-clés. *Sonnailles – Élevage de petits ruminants – Pâturage – Méditerranée.*

I – Introduction

In the areas around the Mediterranean basin, small ruminant farming has been based on the movement of the flocks for centuries. The flocks have been moving –and in some cases are still moving nowadays– following the seasonal growth of vegetation. The movement of sheep and goat flocks takes place annually at the end of spring, from lowland areas to mountain pastures, by means

of walking or by vehicles. In the autumn, the movement follows the reverse path. The primary aim of the movement was to secure feed availability for farm animals, to reduce feeding costs and subsequently to bring the farmers in contact with the mountain communities, usually the places of their own origin (Laga *et al.*, 2005, Oregui and Ruiz, 2005).

Throughout centuries, transhumance livestock farmers have developed a set of simple objects, mild architectural constructions, complex techniques and practices that were considered to be innovations for their time. These were invented, as a consequence, in order to facilitate their daily life and included animal bells, shepherd's crooks, flutes, looms, wool weavings, flaky, capes, "Sarakatsani stables" (made of straws, reeds and clay), dry stone walling, etc. Their preservation and development over time has made a significant contribution to the formation of the natural landscape but also to the social and cultural shaping of the identity of rural societies.

Among the objects mentioned above, animal bells play a vital role in facilitating the farmer's work. Bells are simple metallic objects that transmit the sound at a great distance and help the shepherd's work during the movement and grazing of the animals. According to Bellos (2019), as many as 200 Greek different names have been recorded, in order to describe various species and variations of bells in Greece and Cyprus, especially in areas with developed livestock farming. Their names vary according to the shape, size, weight, material, method and place of manufacturing, the animals for which they are destined, the sound, the local idioms, etc. The main categories into which most bells can be classified according to their construction material and shape are (Fig. 1):

(A) *simple bells*: the vertical intersection at any point is always elliptical,

(B) *"kypria"*: in the form of a truncated cone with two elliptical bases; its height is greater than its width,

(C) *"tsokania"*: in the shape of an isosceles trapezium,

(D) *spherical shaped bells*: a small ball moves freely in the empty inner part of the sphere.

Fig. 1. Main categories of bells according to their construction material and shape: A. simple bell, B. kypri, C. tsokani, D. spherical shaped bell.

The first three categories belong to *open bells* while the spherical shaped are *closed bells*. As far as the method of construction is concerned, bells are separated in *hammered* and *cast bells*. Hammered bells include simple bells and tsokania, while kypria and spherical shaped bells belong to cast bells.

The purpose of this paper was to record the attitudes of small ruminant farmers about the reasons they still continue to use bells in their flocks.

II – Materials and methods

The study sample consisted of 29 small ruminant farmers who use bells on their animals. The semi-structured interview technique was used with a specifically designed questionnaire that included

open-ended questions. The questions regarded the reasons why they still use bells in their flocks, the types of bells, the ways in which bells are hanged and the criteria the farmers have in mind when selecting the appropriate combination of bells to produce the desired sound.

The interviewed farmers came from 10 communities in Western Greece (Epirus & Aitoloakarnania) with a long livestock tradition. They were chosen following the suggestion of fellow farmers who considered them as "experts" in the pastoral bells. The interviews took place in 2018. Content analysis was used to get the data from the interviews. The "sentence" was used as the analysis unit.

III – Results and discussion

The sample profile included sheep and goat farmers rearing Greek native breeds, according to the contemporary extensive livestock farming system. They originated from families with a long tradition in transhumance, livestock breeding and use of bells. Their age varied from 20 to 89 years old (54.00±13.76), while their average educational level was relatively low (82.76% primary school graduates, 17.24% high school or university graduates).

According to the farmers, simple bells should be hanged mainly on sheep, while kypria are fit for goats. They are attached around the neck of the animals, either with leather straps, or with wooden wreaths. The shape of the wooden wreaths varies depending on the type of small ruminant (sheep or goat). They can also bear decorative (carved or painted) patterns, double-click or triple "keys", depending on the breeder's style. Corresponding elements about bells are also found in other Mediterranean countries (Verdier, 2005).

In sheep and goat flocks, the larger bells and the heavier kypria are placed on the "gheshemia" (rams and/or billy goats respectively, usually castrated leading the flock to grazing). Smaller bells are placed on the other animals of the flock (lactating or dry females, lambs, etc.). The farmers avoid using bells (i) in male animals during the mating period to avoid injuring females during reproduction and (ii) in weak lactating females to avoid causing them stress and thus reducing their milk yield.

The so-called "dozen" or "bell array" has a special value for the "experienced ear" of the farmer. It is a staggered raw of kypria that starts from the heaviest and biggest (it produces a lower sound) and ends up to the lightest and smallest (renders a fine sound). Each kypri produces clear, harmonious and distinct sound in relation to its neighbors. These findings have also been confirmed by recent studies (Bellos and Tsironi, 2018; Law, 2014). The number of kypria in the dozen is not defined, but it varies among regions according to the local tradition, the "taste and pride" as well as the financial capacity of the farmer. The dozen usually includes one or two very large simple bells. Although the animals move disorderly during grazing, it is worth admiring the fact that a very pleasant sound effect is produced in the end.

Moreover, the small ruminant farmers still prefer to use bells, particularly in extensive livestock farming systems:

(i) in order to help them locate (even when they are not in their visual field):

- the exact position of flock in the pasture,
- individual animals unable to follow the flock due to injuries or extreme weather conditions,
- animals of some temperament that tend to move away from the rest of the flock and cause damages to the neighboring crops,
- animals from other farms that have entered the flock by mistake,
- animals of their own farm which have accidentally entered other flocks,

(ii) so as to perceive whether the animals are grazing or are in danger and panic due to external enemies (e.g. wild animals' attacks),

(iii) because the animals may easily locate one another with the familiar sounds of their flock and can stay closely packed during grazing to deal, if necessary, with possible external risks,

(iv) because the pleasant sound of the bells promotes animals' tranquility by neutralizing unexpected, intense external noises that could scare the animals,

(v) because the use of many bells in the flocks that deliver high quality sound is a pride, a sign of social recognition and wider acceptance by other farmers and finally,

(vi) in order to contribute to the fun and exhilaration of the shepherd. The sounds and melodies produced by the bells in isolated pastures have been a pleasant company for the shepherd and perhaps his only fun –along with the flute– for centuries.

These findings are in accordance with that of a previous study in Scandinavia which examined the role of cattle and horse bells (2008).

On the other hand, the use of bells in the intensive small ruminants farming systems is extremely limited, since not only it is of no practical use to the farmer, but also because animal management becomes different and more demanding.

IV – Conclusions

This work studied the attitudes of small ruminant farmers concerning the significance of the bells. The results showed that bells help shepherds locate their flock and check whether animals graze serenely or are exposed to external dangers. Moreover, the tinkling of the bells promotes gentle grazing and enhances animals' ability to locate one another. Bells also act as a source of pride and social acceptance by fellow farmers and contribute to the shepherd's enjoyment. Our results are in line with other relevant studies, bringing out the importance of the bells for both the shepherds and the flocks.

Nowadays, modern technological means are available both for the location of grazing animals (e.g. GPS) and for human entertainment (e.g. radios, portable electronic devices, etc.). Nevertheless, a number of livestock farmers continue to place great importance on pastoral bells and spend considerable amount of money to buy bells, whose style (sounds and quality of construction) satisfies their demands.

It seems that the gradual reduction of people involved in animal production as well as the shifting of young people to intensive farming systems is an inhibiting factor for the future use of bells. However, they remain tools that are inextricably linked to our folk art and, consequently, to our cultural heritage, the preservation of which is everybody's duty. For this purpose, every recording of the views of people that are involved in bells construction or use is extremely useful. At the same time, the bells could be integrated into educational awareness actions that will highlight their value as "living organisms" and will inform, especially the young urban people, about the importance they have, mainly for the Mediterranean migratory livestock farming.

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Role of native *Trifolium isthmocarpum* populations in saline soils in Morocco

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Abstract. The potential of previously unexploited crop legume species need to be investigated where environmental and biological stresses constrain the use of more conventional forage crops or where these species are better suited to the needs of sustainable agriculture. The present study have recorded *Trifolium isthmocarpum* Brot., in many different habitats ranging from healthy agricultural lands to abandoned saline areas. The plants maintained nitrogenase activities average 2.04 μmol C_2H_4 $plant^{-1}$ h^{-1} in different habitats. Shoot systems of plants collected from salt-affected soils exhibited higher concentrations of Na^+ and Cl^- than those collected from healthy soils, whereas relative water content was reduced by only 8%. This study suggests recommending the cultivation of *T. isthmocarpum* in moderately salt-affected soils, which are widespread and pose a problem for the farmers of Morocco.

Keywords. Mediterranean – Pasture – Crop – Stress.

Rôle des populations locales de* Trifolium *dans les sols salins affectés par le changement climatique

Résumé. *Le potentiel d'espèces de légumineuses cultivées auparavant inexploitées est à étudier dès lors que des contraintes environnementales et biologiques limitent l'utilisation de cultures fourragères plus conventionnelles ou lorsque ces espèces sont mieux adaptées aux besoins d'une agriculture durable. La présente étude a enregistré les caractéristiques de* Trifolium isthmocarpum *Brot. dans de nombreux habitats différents, allant de terres agricoles en bonne santé à des zones salines abandonnées. Les plantes ont maintenu des activités de nitrogénase moyennes de 2,04 μmol de plante* $C_2H_4^{-1}$ h^{-1} *dans différents habitats. Les systèmes de pousses de plantes prélevées dans des sols affectés par le sel présentaient des concentrations de* Na^+ *et de* Cl^- *plus élevées que celles recueillies dans des sols sains, alors que la teneur en eau relative n'était réduite que de 8%. Cette étude suggère de recommander la culture de* T. isthmocarpum *dans des sols modérément affectés par le sel, qui sont répandus et posent un problème aux agriculteurs marocains.*

Mots-clés. *Méditerranée – Pâturage – Culture – Stress.*

I – Introduction

The Mediterranean Basin is feeling the effects of climate change more than ever. Climate change affects agriculture, reduces fertilizer efficiency and increases evapotranspiration and soil salinity. More than 5% of Morocco's land area is already affected by salinization to varying degrees and 20% of irrigated land produces less (Najib *et al.*, 2017). *Trifolium* is one of the most important forage legumes among the genera of the Fabaceae family, both in terms of its agricultural value and the number of species (Sabudak and Guler, 2009). Several species of *Trifolium* are cultivated in intensive agricultural systems in association with companion grass species in simple or complex seeds mixtures (Lamont *et al.*, 2001). *Trifolium isthmocarpum* Brot., Moroccan clover, occurs as a weed in different habitats (Bennani et Bendaou, 2015; Beale *et al.*, 1993). It grows in moderately saline areas, where traditional forage legumes cannot be cultivated Beale *et al.*, 1993); however, it has not been widely studied despite its good palatability.The aim of our study was to examine the performance of *Trifolium isthmocarpum* in different habitats to evaluate its potential for use as a fodder crop in salt-affected soil in Morocco.

II – Materials and methods

1. Choice of habitats and collection of samples

Two different habitats were chosen. Healthy arable soil (including barley fields in coastal land) and salt affected soils (Fig. 1, Table 1). For the vegetation surveys, a simplified method describing species presence was performed for the different habitats. Homogeneous stands (10×10 m²) were selected, 20 in healthy soils and 20 in salt-affected soil.

Fig. 1. Different sampling locations in Morocco.

Table 1. Soil physicochemical characters of two habitats where *T. isthmocarpum* was recorded

	Healthy soil	Salt affected soil
K (mg/kg)	921 ± 26.8	998.5 ± 12
Na (mg/kg)	411 ± 31,2	2476 ± 78
Mg (mg/kg)	671 ± 17.5	1022 ± 24
Ca (mg/kg)	181.2 ± 11.3	198 ± 18
Fe (mg/kg)	26.5 ± 2.2	57.9 ± 1.9
SO_4^{2-} (mg/kg)	2026 ± 11.1	2999 ± 12
Cl (mg/kg)	2441 ± 22.3	4867 ± 15.9
EC (dS/m)	0.66 ± 0.02	6.1 ± 0.7
pH	7.08 ± 0.2	7.5 ± 0.11
Soil texture	Clay loamy	Clay loamy / Sandy
Rainfall average	360 mm	300 mm

2. Nodulation status and nitrogenase activity

The plants collected from each of the different habitats were analysed to determine nodulation percentage and to enumerate nodule number. The nitrogen- fixing activity (nitrogenase activity) of the legume–Rhizobium symbiosis was determined according to the methods described by Witty and Minchin (1988).

3. Chemical analysis and relative water content

Na^+, K^+ and Cl^- were analysed at the end of the experimental period in the shoots of plants. The concentration of Cl^- was measured following titrametric method. The concentrations of K^+ and Na^+ were determined using a flame photometer (Jenway Ltd, model PFP7; Essex, UK). Relative water content was calculated using: RWC = (FM-DM)/ (TM-DM) ×100, fresh mass (FM), fresh mass at full turgor (TM), measured after immersion of leaf petioles in distilled water for 48 h in the dark, and dry mass (DM), measured after oven drying at 70 °C for 24h to constant weight.

4. Recovery of germination

Recovery of germination upon transfer of seeds from NaCl solution to pure water attributes the initial repression of germination and its subsequent recovery to osmotic factors.

After 7 days, ungerminated seeds from the high concentrations of salt treatments (140 mM and 220 mM) were rinsed three times in distilled water and transferred in sterile Petri dishes with two discs of filter paper saturated with distilled water to study recovery of germination for 20 days.

The recovery percentages (RP) was determined by: **RP = [(*a*- *b*}(*c*- *b*)]100**, where ***a*** is the total number of seeds germinated after being transferred to distilled water, ***b*** is the total number of seeds germinated in saline solution, ***c*** is the total number of seeds.

III – Results and discussion

Table 1 shows variations in soil physicochemical properties of the investigated *T. isthmocarpum*

habitats, which ranged from sandy to clay loamy soils, and from healthy (EC = 0.66 dS/m) to salt affected soils (EC = 6.1 dS/m). Salt-affected soil showed higher concentrations of Na^+, Cl^-, Mg^{2+} et SO_4^{2-} than healthy soils by 6, 2, 1.5, and 1.4 fold respectively.

The studied plants showed high nodulation percentages (ranging between 60% and 97%) and nitrogenase activities (average 2.04 μmol C_2H_4 $plant^{-1}$ h^{-1}) at different habitats (Table 2).

Table 2. Nodulation, nitrogenase activity, shoot ion content and protein content of *T. isthmocarpum* collected from different habitats

	Healthy soil	Salt affected soil
Nodule $plant^{-1}$	69 ± 4.2	56 ± 1.8
Nodulation (%)	97 ± 7.2	80 ± 3.6
Nitrogenase activity (mol C_2H_4 $plant^{-1}h^{-1}$)	3.1 ± 0.02	1.00 ± 0.07
Protein (g/kg dry wt.)	267 ± 9.8	318 ± 5.5
Na^+ (mmol/g DM)	1.14 ± 0.01	2.48 ± 0.18
Cl^-(mmol/g DM)	0.68 ± 0.12	1.7 ± 0.09
K^+ (mmol/g DM)	1.87 ± 0.06	1.33 ± 0.05

The highest values of protein content were recorded in plants collected from salt-affected soils . Shoot systems of plants collected from salt affected soils exhibited higher concentrations of Na^+ and Cl^- than those collected from healthy soils by more than two fold, and showed a reduction in K^+ content of about 30% (Table 2). Various authors have mentioned that *T. isthmocarpum* is found in a broad range of landscapes in Morocco and it is known to be found in coastal areas and to tolerate moderately saline clay soils.

The nodulation percentage varied among individuals collected from different habitats. Sulieman (2014) provides a general overview of environmental constraints to nodulation and nitrogen fixation, as indicative of the importance of environmental stresses to rhizobia. This variation can be also explained by the different prevailing environmental conditions. One of the interesting findings in this study was the important nodulation percentage and nitrogenase activity recorded in the *T. isthmocarpum* plants, which gives the species economic importance as it can be used to enhance soil fertility. The lowest nodulation recorded at the salt affected soil, is likely to be due to decreases in population levels of rhizobia in this habitat. Under severe stress, the requirement for certain essential elements, such as calcium and phosphorus, increases and elevated levels of these elements enhance nodulation and N_2 fixation.

Recovery germination (Fig. 2) for all seed types was significantly affected by 220 mM NaCl compared with 140 mM NaCl ($P < 0.001$). The results show that the effects are initially osmotic, due to the recovery of germination once the salt stress has been removed. The ability to recover germinability has implications for seedling establishment in saline environments, particularly when initial rainfall is insufficient to flush salts from the soil surface. In such situations, imbibed seeds may be able to survive until subsequent rains permit completion of germination. However, this mechanism can only play a role in situations where the soil surface remains moist. Observations of delayed germination in highly saline, relative to less saline, areas of *Melilotus siculus* plots (Nichols *et al*., 2010) suggest this mechanism has importance in this species.

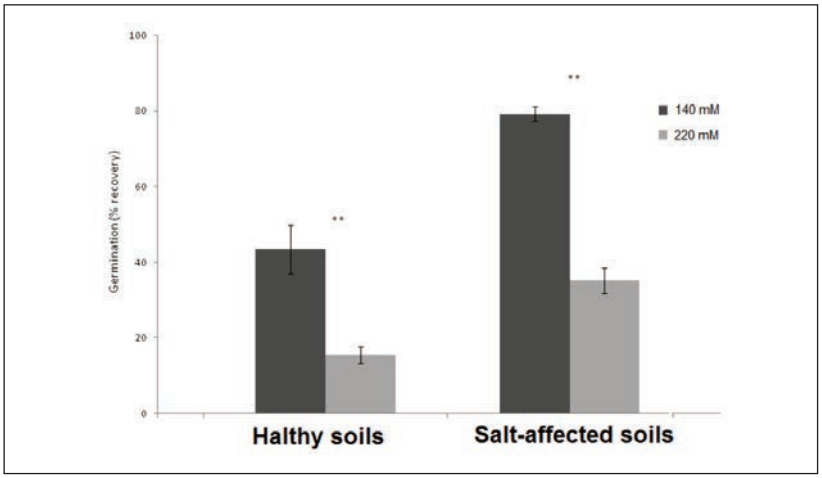

Fig. 2. Percentage of recovery germination, *T. isthmocarpum* seeds, when osmotic stress due to different concentrations of NaCl (140 mM and 220 mM) is alleviated (P < 0.001 according to ANOVA, Tukey test).**

IV – Conclusions

This study suggest recommending the cultivation of *T. isthmocarpum* in moderately salt-affected soils, which are widespread and pose a problem for the farmers of Morocco. However, further work is required to determine the adaptive significance of this trait.

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Management strategies to improve environmental and economic outcomes of sheep farms in Norwegian coastal and fjord areas.
1. Sustainable use of home-grown feed resources and rangeland pastures

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Abstract. Norway has vast rangeland resources (292 361 km^2) with an estimated carrying capacity of nearly four million lambs and sheep – twice the current number. However, an intensive production system has led to concentrate-dependent indoor feeding and poor utilisation of rangelands and homegrown feeds. In coastal and fjord areas, such intensive production systems limit the use of open landscapes for sheep grazing during the winter. It influences the delivery of ecosystem services such as soil fertility, landscape preservation and biodiversity. The importance of developing animal and environment-friendly sheep grazing systems has also been highlighted recently, emphasizing the use of natural resources that cannot be used for more intensive cropping enterprises. Extensive grazing systems are also capable of producing "green" food products that contribute to regulating soil health, water and nutrient cycling, soil carbon sequestration, and recreational environments. These are appreciated by consumers and society at large and may be economically sustainable for farmers. In this paper, the economics of the current sheep feeding practices are compared with a more extensive system allowing for higher intakes of on-farm feed resources using a linear programming model. Changes in the current management practices have the potential to increase lamb meat production and lower mutton production, in addition to improving the year-round supply of fresh meat. The utility of smaller frame size breeds needs to be explored as a means of achieving these goals. These breeds may also supply a market for smaller meat joints and cuts designed for rapid preparation of meals for time-constrained consumers.

Keywords. Home-grown feed – Rangeland – Intensive production system – Ecosystem services.

Stratégies de gestion visant à améliorer les résultats environnementaux et économiques des élevages ovins dans les fjords et zones côtières de Norvège. 1. Utilisation durable des ressources fourragères locales et des pâturages

Résumé. *La Norvège abrite de vastes surfaces de pâturages naturels (292 361 km2) qui pourraient nourrir quatre millions d'agneaux et brebis, soit deux fois le nombre actuel. L'intensification de la production a cependant mené à un système d'élevage de avec basé largement sur des concentrés importés et moins sur l'utilisation des produits de la ferme et des pâturages naturels. Au bord de la mer et des fjords, ce système intensif limite le pâturage ovin. Ainsi les services écosystémiques comme l'enrichissement du sol par la fumure, la préservation du paysage et de sa biodiversité, seront impactés. Récemment on a souligné l'importance de développer des systèmes de pâturage ovin qui respectent l'environnement et les animaux, et qui valorisent des*

espaces naturels non cultivables. Les systèmes de pâturage extensifs peuvent produire des aliments « verts », et aussi contribuer à la santé du sol, à la séquestration du carbone, et maintenir des espaces adaptés aux activités touristiques et de loisir. Ceci peut être apprécié par les consommateurs, et la société en général, et améliorer les revenus des éleveurs. Dans ce travail nous décrivons les pratiques intensives actuelles d'alimentation des ovins, et les comparons aux systèmes extensifs qui augmentent l'utilisation des ressources locales. Cette comparaison est réalisée à l'aide d'un modèle de programmation linéaire. Des changements dans les pratiques de gestion actuelles pourraient augmenter la production de viande d'agneau et réduire la production de viande de brebis, en plus d'améliorer l'offre de viande fraîche toute l'année. L'utilité des races de petite taille pour atteindre ces objectifs est explorée car il est possible que les découpes de viande plus petites, permettant une préparation rapide des repas, pourraient intéresser les consommateurs pressés.

Mots-clés. *Aliments produits localement – Pâturage – Systèmes de production intensifs – Services écosystémiques.*

I – Introduction

Norway, being the largest sheep (and goat) meat producer in Scandinavia, has only 2.7% arable land and vast rangeland resources (292 361 km^2) with the capacity to hold nearly four million sheep, twice the current number . Thus, a situation with so much rangeland resources, little arable land and the highest sheep population in the region highlights the importance of grazing to better utilise the rangelands, especially for sheep production. Grazing the vast rangeland resources might be both efficient and environmentally friendly as well as economically sustainable for the sheep farmers.

There are ongoing debates about livestock production, meat consumption and its linkage with climate change in Norway and elsewhere. At one extreme, ruminants are considered a significant contributor to our planetary woes, while on the other hand, it is believed that "grassfed" ruminants offer a route to environmental, including climatic salvation (Garnett *et al.*, 2017). Willett *et al.* (2019) suggest a significant reduction in global meat consumption. Also from a global perspective, it might be justifiable to moderate red-meat consumption, currently around 55 kg per capita of which 5.5 kg is sheepmeat, in Norway. In areas not suitable for crop production, due to unfavourable climate and land topography, livestock grazing or wild herbivores remain for converting rangeland pastures into human edible protein (Mottet *et al.,* 2017). According to, the current paradigm for mitigating the effects of climate change, the promotion of intensive meat production from monogastric animals may be misleading. Arguments against red meat production rest on the assumption that if grazing ruminants are removed, greenhouse gas (GHG) emissions will be reduced. In fact, in the absence of domestic ruminants, the rangeland habitats will probably be taken over by other wild methane-producing herbivores. However, according to Grønlund (2013) and Thoring (2016), on Norwegian intensive farms, production of one kilogram of lamb or chicken meat will require equal amounts of concentrate feed. For small ruminant production to be credible, a pasture-based feed ration is vital. Bhatti *et al* (2019) argue that by using lighter sheep and goat breeds rather than the dominant heavy "Norwegian White Sheep" (NWS), a larger area of the grass-based grazing ecosystem may be utilised. By diversifying the sheep production systems, farmers may strengthen their role in maintaining important grassland agroecosystems for delivering public good for conservation of agricultural landscape, biodiversity, soil fertility, animal welfare and quality products linked to the territory for the Norwegian society (Bernués *et al.,* 2015).

Furthermore, the carbon footprint could be reduced by efficient whole carcass utilisation. An extensive grazing system has the capacity to produce "green" food products and services that will contribute to regulate and improve soil health, water and nutrient cycling, soil carbon sequestration, and the recreational environment. Such improvements, which are appreciated by consumers and society, may also be more economically sustainable for farmers.

Norwegian sheep farming, particularly in Western Norway, the hub of sheep farming, will probably be more accepted by society when it is practiced on farmlands and farm pastures that cannot easily be transformed into crop or vegetable production due to climatic, land or soil constraints (Bhatti *et al*., 2019). In Western Norway, sheep farmers cannot diversify their agricultural system to the same extent as farmers in other Scandinavian countries have access to more land suitable for grain crops and vegetable production (Karlsson *et al.,* 2017). The objective of this study was to calculate the economics of adjusting the traditional sheep farming system in Western Norway to allow for increased utilization of homegrown winter feed and rangeland grazing.

II – Materials and methods

The economics of the current (semi-intensive / intensive) sheep feeding practices with more extensive feeding practices are compared using a linear programming (LP) model. The Norwegian White Sheep was used for the modelling. In the Norwegian National Recording scheme, 70 % of the ewes belong to this crossbred type of sheep. The average number of lambs per ewe at birth (in April) and at the end of grazing (in September) are 2.31 and 1.89, respectively. BW of lambs in the fall is 43.7 kg, and mature BW of ewes (5 years) is approximately 100 kg (Sauekontrollen, 2018). In the current practice, lambs give birth at one year, lifespan of ewes is 3-4 years, lambing takes place around April 15 and slaughtering of lambs on September 20. Three alternative more extensive practices were investigated:

1. Postponing lambing until the onset of grazing (around May 1) and slaughtering around October 5.
2. Overwintering of female lambs and marketing them as yearling lambs in July or August.
3. Postponing initial lambing until 2 years, assuming ewes then would be kept in the production system until five or more years.

The extensive system allows for higher consumption of on-farm feed resources and decreases the dependency on concentrates. Changes in the prevailing management practices have the potential to increase lamb meat production compared to mutton production, in addition to improving the year-round supply of fresh meat. Moreover, the amount of concentrates for yearlings is lowered by postponing the initial lambing until 2 years of age since the non-bred ewe lambs have lower feed requirements compared to pregnant-ewe lambs. For ewes, the amount of concentrates during the indoor feeding period after lambing is lowered when lambing occurs closer to the start of the grazing season.

To study the economics of the above questions, a deterministic Linear Programming (LP) model of a sheep farm was employed. The mathematical formula of an LP optimisation model (Luenberger and Ye, 1984) is: Max $Z = c's$ subject to $Ax \leq b$, $x \geq 0$.

Here Z is the farmer's objective function or gross margin (GM), i.e. total returns from livestock and government payments, minus variable costs. The fixed costs were not affected, so a ranging of alternatives according to GM would be similar to arranging according to farm profit. Moreover, x is a vector of activity levels; c' is a vector of marginal net returns of activities. A is the matrix of technical coefficients showing resource requirements by the activities; b is the vector of right-hand side values of resources such as farmland and semi-cultivated farm pastures, farm workforce and requirements such as feed energy, relating to the constraints. Constraints also account for crop rotation, use of manure, area payments, and herd replacement.

The current version of the model, described in Asheim *et al*. (2014), was parameterised with other data (average for the three years 2014-2016) from 18 sheep farms in the region and the cost data were inflated to the price level in 2018. Moreover, the prices were updated (Hovland, 2018), and we applied the support system agreed for the 2019/2020 season. The price of lamb was 66.10 NOK

per kg while mutton and young sheep 1-2 years were 7.18 and 10.18 NOK per kg respectively. Additionally, basic and rural price support amounting to 9.06 NOK per kg was assessed for all meat. The minimum amounts of concentrates are displayed in Table 1.

In basic scenario, the initial lambing was at one year and, based on the farm accounts, replacement of ewes was to take place after 3.25 years, giving a replacement rate of 0.31. Lambing occurred on April 14, and the average slaughter date was on September 20. The net number of lambs per ewe was set to 1.33 based on the farm accounts. The unmated lambs were assumed often kept outdoors during the first winter with supplementary feeding of only 0.15 kg of concentrates per day. The pasture would be free but sufficient for maintenance feed only. These lambs were moved to regular farm pasture in the second summer when the regular flock were grazing in the mountains. They were then prepared for marketing in the summer with slaughter day set to August 12 before the autumn grazing of the regular flock starting around September 5. Such lambs would require little supervision during the second year and no extra time during lambing as they were not mated.

Table 1. Minimum amount of concentrate by different age categories of sheep mated and unmated lambs (Kg per day)

	Ewes		Lambs, <1 year	
Concentrate type and season	**> 2 years**	**1-2 years**	**Mated**	**Unmated**
FORMEL Fiber, winter	0,2	0,3	0,5	0.15
FORMEL Sheep, after lambing, per lamb	0,5	0,5	0,5	–

III – Results and discussion

The model was at first run in a basic alternative calibrated to reproduce the current situation for the farms. The results are displayed in Table 2 together with the alternatives with postponed lambing until the start of the grazing time. The opportunity for keeping surplus female lambs for an extra year and selling them next summer as well as changing initial lambing age and replacement rates were assessed. The ram lambs were slaughtered around half a year old to avoid off-flavour on the meat. For welfare reasons, routine castration of lambs is not permitted in Norway, and hence only females may be used as store lambs (in Norwegian “Fjorlam”).

Table 2. Gross margin in Norwegian Kroner (NOK, 1 NOK = 0.10 Euro), number of sheep and Fjorlambs of the NWS breed, use of feed, roughage yields and production in a basic solution and by altering lambing time, keeping surplus females another winter (Fjorlam) and delayed first lambing until 2 years of age without and with extended ewe durability

	Gross margin	Breeding sheep	Fjor-lambs	Concentrate FEm*/ sheep	Roughage FEm*/ sheep	Yield FEm*/ ha	Roughage FEm*/ total	Hired work, h
Basic, lifetime 3.3 years	401 425	172	0	115	387	2 711	66 630	570
Lambing 16 days later	371 146	168	0	128	380	2 588	63 614	510
Surplus females for Fjorlam	266 176	139	51	109	476	2 694	66 222	579
First lambing at 2 years	350 867	193	0	70	345	2 714	66 717	589
2 years + lifetime 5.3 years	407 981	182	0	81	367	2 713	66 679	553

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On our average model farm, autumn pastures were a limiting factor and lambing later in spring was not profitable. However, the situation varies: when readily accessible and autumn pastures on farmland are available, improved economic performance for late-lambing ewes should be possible.

Our second option was to use surplus ewe lambs for store-lambs with slaughtering in the middle of the second grazing season. The number of lambs available for this process would depend upon the number of female lambs born and the number required for replacement. The key question is what feeding such lambs would require. We assumed feed requirements were lowered since the lambs would grow slower and could use some pastures during the winter. Still, by requiring that available female lambs were kept and sold as sheep the following year, the gross margin fell substantially in spite of the extra support for sheep.

The third examined option was to delay initial lambing until 2 years. This would require feeding for another winter, but presumably would require substantially less feeding than the regular practice of lambing at 1 year of age. We hypothesize that such slow fed lambs would take longer to attain commercial liveweights and would make better use of winter pasture in the first year: the question is how much longer. Calculations with a similar lifetime of 3.3 years yielded a negative result compared to the basic, however increasing average lifespan to 5.3 years would improve the results. The results are due to less low-priced mutton and more meat production on better-paid lambs even though the sheep had no lambs in their first year. The break-even seems to be around 5 years for the NWS breed.

IV – Conclusions

Using the NWS breed, we find that neither delayed lambing nor production of 1-1.5-year-old lambs would provide greater profitability in Norwegian sheep farming. Lambing later in spring may work on farms having abundant access to high-quality mountain – or autumn pastures, but not if they were already utilized by the regular flock. The main problem with meat production on over-wintered lambs was the substantial decline in price compared to a regular half-year-old lambs. However, farmers should consider moderate feeding of replacement lambs combined with first lambing at 2 years of age. By increasing the breeding life of ewes from 3.3 to 5.3 year, an increase in profitability may be achieved. The breakeven seems to be around 5 years of age for this breed.

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Management strategies to improve environmental and economic outcomes of sheep farms in Norwegian coastal and fjord areas.
2. Effect of ewe size and breed characteristics on rangeland utilisation and sustainable management

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Abstract. Morphological and productive aspects of Norwegian sheep have developed over time and adapted to the diverse environment of the country. To increase weight and reproductive efficiency, native sheep were crossed with UK breeds before 1900. Subsequent selection programs eventually led to the creation of the heavier (adults often > 90 kg) Norwegian White Sheep (NWS), today constituting 70 % of the recorded ewes. The modern Spæl sheep, mostly <75 kg and accounting for 21.5% of the recorded ewe population, originated from the native short-tailed breeds that are smaller and prefer grazing in higher areas. The Norwegian terrain is rugged, but with rich summer pastures in-between, possibly making Spæl a better-suited breed than the NWS, at least in some environments in the coastal and fjord areas. Demand for fresh meat year-round may also favour production changes. Efficient and increased use of local feed resources, and knowledge of ewe size, litter size, growth patterns, and pasture area utilisation, is essential for a changeover to Spæl. Spæl may be more efficient than the NWS in terms of less dependency on concentrates, and better utilisation of local pastures. Smaller adults imply reduced housing demands, and it may also be better suited for being outdoor in the mild winters in the area. In this paper, we compare the farm profitability of the two breeds using a linear programming model worked out for the coastal and fjord areas. The impact of ewe body weight, housing capacity, and meat produced per unit of concentrate are discussed.

Keywords. Ewe size – Grazing – Concentrates – Spæl sheep.

Stratégies de gestion visant à améliorer les résultats environnementaux et économiques des élevages ovins dans les zones côtières et les fjords norvégiens. 2. Effet de la taille des brebis sur l'utilisation des pâturages et la gestion durable

Résumé. *Les aspects morphologiques et productifs des moutons norvégiens se sont développés et adaptés à la diversité du pays et aux systèmes d'élevage. Pour augmenter le poids et améliorer les performances de reproduction, les moutons indigènes ont été croisés avec des races britanniques avant 1900. Des programmes de sélection ultérieurs ont finalement abouti à la création d'un mouton blanc plus lourd (adultes> 90 kg), le NWS, qui représente aujourd'hui 70% du cheptel ovin en Norvège. Les moutons 'Spæl' modernes pèsent pour la plupart <75 kg et ne représentent que 21.5% de la population ovine. Ils proviennent des races indigènes à queue courte, qui sont plus petites et préfèrent pâturer dans les zones plus élevées. En Norvège le terrain est accidenté, avec cependant de riches pâturages d'été, faisant de Spæl une race peut être mieux adaptée que la NWS, du moins dans certains milieux des zones côtières et des fjords. La demande de viande fraîche toute l'année peut favoriser quelques changements dans les modes de production. L'utilisation efficiente et accrue des ressources alimentaires locales pour les animaux, ainsi que la connaissance du format des brebis, de la taille de portée, des modèles de croissance et de l'utilisation des pâturages, sont essentielles pour passer à la race Spæl. La Spæl pourrait être plus efficiente que la NWS avec moins de dépendance aux concentrés et une meilleure*

utilisation des pâturages locaux. La moindre taille des adultes implique une réduction des besoins de stabulation en hiver et pourrait être mieux adaptée à un hivernage en extérieur pendant les hivers doux de la région. Dans cet article, nous comparons la rentabilité entre exploitations utilisant l'une ou l'autre race, à l'aide d'un modèle de programmation linéaire élaboré pour les zones côtières et les fjords. Les effets de la taille de l'animal, de la capacité de stabulation, et de la production de viande ovine par unité de concentré, sont discutés.

Keywords. *Format des brebis – Pâturage – Concentrés – Race spæl.*

I – Introduction

Due to the long winters, the majority of Norwegian sheep-farmers operate within strict environmental boundaries with in-door feeding from October (autumn) to May (spring). Availability of homegrown feed, mainly grass-silage, is limited due to the short growing season on smaller agriculture farms. During the summer months, on the other hand, high quality pastures and vast rangeland resources are freely available, providing more than 50% of the annual feed consumption of the sheep herds (Asheim & Mysterud 1999; Bhatti *et al*., 2019b). Farmers are seeking to optimise the number of lambs per ewe to have more lambs ready for slaughter in the fall. Usually, ewes and yearlings can sustain twins and singletons during the grazing period, whilst triplets require the availability of better pastures.

The Norwegian White Sheep (NWS), a composite prolific breed weighing approximately 100 kg when adult and kept for meat and wool, constitutes 70 % of the recorded ewe population. At birth and at the end of the grazing season (October), the number of lambs per ewe is 2.3 and 1.9, respectively, with a final lamb-BW of 43.7 kg (Sauekontrollen, 2018). The higher prolificacy comes at a cost of extra management required for the triplets thereby rearing lambs artificially using milk powder and concentrates in addition to lambing difficulties. In a study with ewes having triplets (Dønnem, *et al.,* 2109), 48% of deliveries occurred naturally, while minimum and high levels of assistance were required for 30 and 22% of the lambings, respectively. NWS needs continuous surveillance during lambing. Sheep farming is normally a part time occupation in Norway, and the lambing time puts a heavy load on the care-takers.

The indigenous short-tailed sheep (Spæl) is the second most common breed in Norway and includes 21.5% of the recorded sheep population. There are further five sub-types within Spæl. The White Spæl (9.6%), kept for meat and wool, is the most common Spæl. The average number of lambs per ewe at birth and in September (end of grazing) are 2.1 and 1.8, respectively. BW of lambs in fall is 41.8 kg, and mature BW of ewes (5 years) is approximately 75 kg (Sauekontrollen, 2018).

In the national recording scheme, involving 52.1% of the approximately one million winterfed sheep in the country, the productivity indicators give an advantage to the heavier NWS-Sheep. Though, when calculating lamb production in the fall per 100 kg ewe-BW, the performance of NWS and White– Spæl were 83 and 100 kg, respectively. This shows that Spæl is the most efficient breed for converting roughages and pasture into edible food.

Compared with NWS, anecdotal evidence indicates that Spæl sheep stay together in larger flocks, cover longer distances and use the steeper hill-sides. The Norwegian terrain is rugged with rich summer pastures in-between, making Spæl a better-suited or complementary breed to the NWS. Also, the Spæl ewe would have a longer breeding life. Spæl has more browsing tendency than that of NWS, possibly making this breed more suitable for managing the traditional pastures (Steinheim *et al.,* 2005; Stenheim *et al.,* 2003). Furthermore, recent findings indicate no differences in meat quality between yearlings (mutton) and lamb's meat for Spæl, while significant differences were observed for NWS (Bhatti *et al.,* 2019a). The price difference between lamb meat and mutton is large thus making lamb production much more profitable.

The coastal farmers, due to the milder climate, may graze their sheep in high-mountains during summer, lower-mountains during fall and finally along the fjord during wintertime. Still, such an adaptation is not common. Both inland and coastal farmers routinely sell lambs in September-October, resulting in pressure on slaughtering-facilities and shortage of fresh lamb-meat in the off-season.

In the UK, the "British Lamb" is usually sold fresh to compete with imports of frozen New Zealand lamb. We believe that, in Norwegian coastal areas, well-managed store lambs (in Norwegian called as *Fjorlam*) consuming home grown feeds might offer an opportunity for the farming industry in terms of regular cash flow and support sustained supply of quality meat throughout the year. A well-planned system of store lamb production with extended grazing season coupled with the appropriate concentrate supplementation may improve feed utilisation, profit margins and the environment. Increasing demand for fresh meat year-round may favour the production changes, and such extensive production systems would allow for more lambs to be slaughtered in the period from early winter to autumn.

The objective of this study was to examine the farm profitability of the Norwegian short-tailed Spæl breed (White Spæl) in an extensive system with three alternative practices at the Norwegian coastal and fjord areas.

II – Materials and methods

To compare the economics of rearing Spæl breed (White Spæl) in an extensive system with three alternative practices, we applied a Linear Programming (LP) model as described by Asheim *et al*., (2014). The model was updated to reflect the price level in 2018 and parameterized with i.a. data from 18 sheep farms in the region (Bhatti *et al.,* 2019). Moreover, we used data assuming the weights and growth rates of the White Spæl for modelling purposes. The daily feeding requirements, including the minimum amounts of concentrates, were lowered by 25% compared to the rates for the NWS breed due to the smaller size of the breed.

In the current practice, we assume : yearlings giving birth at one year, a 3-4 years lifespan of ewes, lambings taking place around April 15 and slaughtering of lambs on September 20, similarly to the NWS breed.

The extensive system includes three alternative practices:

1. Postpone 1st lambing until the onset of grazing (around May 1) and slaughtering around October 5.
2. Overwinter female lambs and market them as yearling lambs in July or August.
3. First-lambing at two years, assuming a breeding-life for ewes of five years.

III – Results and discussion

The profitability was slightly higher for Spæl than for NWS (presented in the first paper). Due to the smaller size of the Spæl, feed intake is lower and more ewes can be maintained during the winter. In addition to the production of more lamb's meat per unit of winter feed, the Norwegian lump sum subsidy payments per animal are favouring less-heavy animals (lamb and sheep). The lump sum subsidy payments are less for the sheep herds with more than 150 sheep-heads while lambs get paid based on certain carcass quality (EUROP). We present the results of modelling the farm-income for a herd of Spæl-Sheep in Table 1.

Table 1. Effects of delayed time of lambing, use of store lambs (Fjorlam), age of first-freshening and ewe's breeding life on farmers' income

	Gross margin	Breeding sheep	Fjor-lambs	Feeding, Concentrate	Roughage FEm*/ sheep	Roughage FEm*/ ha	Production total Fem*	Hired work, h
Basic, lifetime 3.3 years	423 277	191	0	98	348	2 699	66 354	754
Lambing 16 days later	390 760	193	0	118	326	2 559	62 900	763
Surplus females for Fjorlam	350 828	140	51	75	458	2 611	64 171	583
First lambing at 2 years	365 351	195	0	46	332	2 632	64 687	593
2 years + lifetime 5.3 years	433 421	199	0	65	334	2 703	66 435	718

* 1 FEm = 6.9 MJ net energy.

The results were somewhat similar for the alternative with postponed lambing as for the NWS breed. In alternatives investigated in this study, lambs were supplemented with concentrates due to a shortage of grazing areas in the fall. They would also graze more on arable land which would result in lower production of silage for winter feed. For farmers having more pasture availability in the fall, either the home-near outfield or farm pastures, later lambing may prove more profitable.

In our modelling, we assume the same daily work input per sheep irrespective of breed. The Spæl requires less work per kg of meat produced. Spæl also maintains the "lamb's meat characteristic" even for overwintered store lambs thereby making it a more suitable breed for an extended fresh-meat season (Bhatti *et al*., 2019a).

Given the huge price differences between mutton and lambs' meat, the offtake of sheep meat needs to be as low as possible. Longer breeding life is possible, particularly for farmers having Spæl.

IV – Conclusions

Until today, the focus of the Norwegian sheep industry has been on the production of lamb's meat and wool from the synthetic NWS-breed. Increased use of the Norwegian short tailed Spæl or similar breeds either as a supplement, or an alternative parallel breed to the NWS might be a way forward particularly in the coastal and fjord areas of the country. We suggest overwintering of Spæl ewe lambs for maintaining open landscapes and biodiversity. To make this happen, we recommend changes in the subsidy scheme in favour of store lamb production. Also, whenever possible, the breeding life of ewes should be prolonged to increase the offtake of lamb's meat and keep the cost of rearing at a minimum.

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Sorghum bicolor (L.) Moench, importance and utilization in the northwest of Morocco

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Abstract. Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop for animal and human nutrition. With climate change problems, due to its low water requirements, sorghum appears to be an important crop in Morocco, for areas with poor soil and in the absence of any irrigation. Our prospection consisted in collecting sorghum ecotypes from farmers in the northwest of Morocco. In parallel with the field trips, surveys were carried out on cultural techniques, different uses, production constraints and cultivation in the region. Area cultivated with sorghum varied from 150 m² to 1.5 ha, and 80% of farmers rotate with wheat or barley. Sorghum is harvested from September to November, and the yields are influenced by the weather conditions. They are low and range from 2 tons/ha to less than 200 kg / ha. The major problems of sorghum in the region are that of birds devastating grains, and that of cryptogamic diseases like *Sporisorium ehrenbergii* and nonagrioid Sesamia attacks. 80% of the farmers cultivate the sorghum for animal and human self-consumption. Sorghum is used in the feeding of cattle, sheep and poultry. The average price of sorghum is 5 dh/kg. It increases to 8 dh/kg during the sowing period.

Keywords. *Sorghum bicolor* – Cultivation – Utilization – Northwest of Morocco.

Sorghum bicolor, importance et utilisation au Nord du Maroc

Résumé. *Le sorgho* (Sorghum bicolor *(L.) Moench) est une culture céréalière importante dans le domaine de la nutrition animale et humaine, au nord du Maroc. Avec la problématique du changement climatique, de par son cycle réduit et ses faibles besoins en eau, le sorgho semble être une culture importante à utiliser sur un sol pauvre en absence de toute irrigation. Notre prospection a consisté à collecter 24 écotypes de sorgho auprès des agriculteurs de la région de Tanger Tétouan El Hoceima. Parallèlement aux visites de terrain, des enquêtes ont été menées sur les techniques culturales, les différents usages, les contraintes de production dans la région. La superficie cultivée en sorgho varie entre 150 m² et 1,5 ha et 80% des agriculteurs l'utilisent en rotation avec le blé ou l'orge. Le sorgho est récolté au début de la saison des pluies et les rendements sont influencés par les conditions climatiques. Ils sont faibles et vont de 2 tonnes / ha à moins de 200 kg / ha. Les principaux fléaus du sorgho dans la région sont celui des oiseaux dévastateurs des céréales et celui des maladies cryptogamiques telles que Sporisorium ehrenbergii et les attaques de Sesamia nonagrioides. 80% des agriculteurs cultivent le sorgho pour leur propre consommation, animale et humaine. Le sorgho est utilisé dans l'alimentation des bovins, des ovins et de la volaille. Le prix moyen du sorgho est de 5 dh / kg. Il peut atteindre 8 dh / kg pendant la période de semis.*

Mots-clés. Sorghum bicolor – *Cultivation – Utilisation – Nord-ouest du Maroc.*

I – Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important grain crop in the world, after maize, wheat, rice and barley, in terms both of production and of area under cultivation (FAO, 2013). Africa and India are large producers and account for more than 70% of world production (FAO, 2013). However, in Morocco sorghum is not an important cereal crop. It is grown and maintained as an ancestral crop only in the northwest of the country where it is used as food and feed (Kadiri and Ater, 1997). Sorghum is considered as a moderately threatened crop, compared to wheat, rye, peas and chickpeas that are considered highly threatened (Ater and Hmimsa, 2008).

To preserve these local resources from genetic erosion, the collection of germplasm and *ex-situ* conservation is a necessity (Mekbib, 2012). In addition, to study the new options of ruminant feed supplementation by this crop, it is important to understand the diversity of this crop in its geographical area as well as the traditional systems of its conduct. The aim of this study was to characterize sorghum cultivation throughout the northwest region of Morocco.

II – Materials and methods

The study was conducted in Tangier-Tetouan-El Hoceima region from 3rd September to 10th October 2018. It consisted in collecting sorghum ecotypes from fields in order to characterize their agro-morphological and bromatological aspects. Data were collected from farmers using a participatory research evaluation method based on observations and interviews. This area was divided into two agro-ecological zones: i) the Rif mountains, which brings together a silvopastoral ecosystem and a subsistence agricultural activity, and ii) the Tangier-Larache region with more developed sorghum cultivation.

The collected information related to cultural techniques, plant morphological description, different uses, production constraints and the future of the culture in the region. The information was collected from both sexes and different age groups. The interviews with the elderly were of great help.

III – Results and discussion

1. Vernacular name

Local varieties in northwestern Morocco belong to a single race "*durra*" with only two distinct forms: cernuum (draa hamra) and durra (draa bayda), as (Kadiri and Ater, 1997) described them. Farmers distinguish among the two forms according to the color of the seeds. In the Jebha region, they call it "*Draa sghira*" referring to the size of the seeds that are small compared to the large size of corn seeds "*Draa kbira*". In the province of Larache, they call it "*kssiba*" which means little cane. This diversity of vernacular names reflects the diversity of sorghum ecotypes in this region.

2. Cultural techniques

In the agrosystem of the Rif, sorghum is cultivated on poor, hilly and rocky soils called "*ferrich*" in the local jargon. It is grown in heavy clay soils called "*Tirs*" in the province of Tangier.

According to farmers, sorghum is an easy crop in terms of farming techniques. Only soil preparation requires time and effort. 80% of farmers do a single tillage in spring. Farmers whose plots exceed one hectare use mechanical soil tillage. Those with small plots use animal traction. On average 8 days are needed for the preparation of the soil and the sowing of 1000 m² using animal traction while it takes only 1 hour for the mechanical tillage of one hectare. The duration depends on the speed of the machine, soil texture and humidity.

100% of the surveyed farmers cultivate sorghum under rainfed conditions, the sowing of sorghum taking place between early March and the end of May. Seeding is done manually with an average amount of 15 kg seeds/ ha.

The cultivated area of sorghum varies between 150 m² and 1.5 ha. Occupied sorghum plots are small in the Rif agro-ecosystem compared with the provinces of Tangier and Larache. The cultivation of sorghum is threatened by the cultivation of cannabis.

80% of farmers rotate sorghum with wheat or barley. They claim that the roots and residues of these two crops contribute to the fertilization of the land. However, the best results are obtained after a legume harvested in green (Noutfia and Baya, 1997).

Sorghum is harvested at the end of summer. Harvesting begins around the end of August and lasts until the end of September for certain late varieties. Premature varieties prevail in arid areas while late varieties dominate in wetlands. In mountain areas, the harvest is done manually using a sickle. Some farmers tear the whole plants to cut the panicles later. They dry the rest of the plant and use it to cover other crops. In plains where cultivation occupies large areas, the harvest is mechanized. In this case, at harvest the panicles must be dry enough to prevent their loss by the machine. To avoid losses due to storage, the panicles are dried under the sun. The grains of sorghum are separated from the panicles by a hammering operation using a pestle after drying.

Yields are influenced by climatic conditions. They are low and range from 2 tonnes / ha to less than 200 kg / ha. Thus, local varieties under optimal conditions produce low yields compared to improved varieties. Yet, sorghum yield, production and surfaces are stable compared to other cereals (Chantereau and Cruz, 2013).

3. Crop diseases

Our prospection concerned the whole region of Tangier Tetouan El Hoceima. But in general, we noted differences between the agrosystem of the Rif and the Tangier-Larache area. The major threat of sorghum in the region is grain-eating birds. The intensity of the attack is high in the area of Taounate El Hoceima because the sorghum plots are rare and scattered.

Another threat is cryptogamic diseases. 7% of the observed fields in the region were affected by panicle elongated coal (*Sporisorium ehrenbergii*) (Fig. 1.a). It is called "*kohhila*" in the local jargon. 50% of the fields where the coal had been encountered were completely infested because the spores are easily disseminated in the air. Farmers do not take steps to avoid or alleviate losses. Only one farmer buried the infected crop residues, but it was too late because the seeds were perforated and always exposed to the wind which scatters the spores.

The region of Tangier, especially, experiences an attack of Sesamia nonagrioide (Fig. 1.b). 100% of farmers in this area reported this disease. They call it "*douda*" in the local jargon to refer to worms or lepidopteran larvae. This larva perforates the stem from the inside but does not affect the panicle. Farmers do not make any prevention or treatments because they do not see a loss in terms of yield, probably because the attacked plants produce new healthy stems that replace the infected ones. To reduce the spread of this disease, when the plant is at a height of 20 cm high, one of the farmers allows his sheep flock to graze for half a day, in order to cut the upper parts and eat the infected stems.

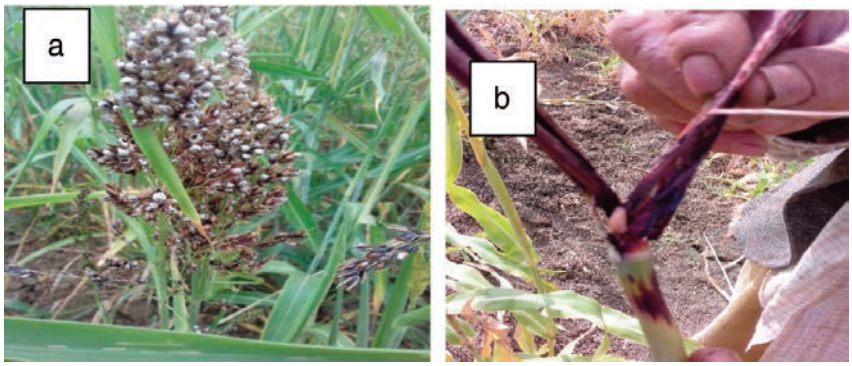

Fig. 1. Sorghum diseases in northwest of Morocco.

4. Sorghum utilization

Sorghum is a moderately threatened crop (Ater and Hmimsa, 2008). 80% of farmers grow it for animal and human consumption. In the Rif Mountains, sorghum is consumed only by the elderly as semolina or flour for bread making. Others grow it as a fence in gardening plots.

Sorghum is used in the feeding of cattle, sheep and poultry. Breeders accuse sorghum of poisoning livestock when they consume young plants or regrowths. They distinguish between red sorghum which is more toxic compared to white sorghum. This problem decreases with the growth of the plant and ends at the heading stage.

Sorghum grains are used during the summer season. For 30 farm chickens, farmers use as feed 1.5 kg of sorghum in the morning and 1.5 kg in the evening. Fowls are sold in local markets; a large cock can be sold 100 to 120 dh while a small one is sold 60 to 70 dh.

Breeders in the region have two cows and two calves on average. For lactating cows, they give an average of 0.5 kg of sorghum grain mixed with other seeds for an average of 2 kg of concentrate per animal per day. They mix it with barley, wheat and cereal bran.

The farming system is agro-pastoral. In the summer, farmers harvest crop residues. The stems and leaves remaining in the plots are grazed by animals. In this state, the cows consume it without any problem. The breeding system is breeder-fattener, so half of the amount of milk produced is given to the calves. On average, manual milking generally yields of about 4l / cow / day.

Sorghum grains are also used in the fattening of the calves and sheep for the *Aid* ceremony, especially during the finishing phase which requires a rich energy supply. They are mixed with faba beans in addition to mineral complements. With a starting weight of 150 kg and a final live weight of 350 kg, in a period of 3 months, the farmer can sell this calf at 15 000 dh.

The average price of sorghum is 5 dh / kg. This amount can increase to 8 dh / kg during the sowing period. Farmers state that sorghum is less profitable compared to other crops, but the ease of farming techniques encourages them to cultivate it.

IV – Conclusion

Sorghum is a traditional crop used for animal and human nutrition in traditional area of northwest morocco. It is cultivated within a rainfed system and its yields depend on climatic conditions. Surveys are important to understand its cultivation and utilization in the area, but measurements should be taken to improve the agro-morphological characterization of its agro-ecotypes and ultimately their utilization.

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Use of grazing according to the kidding period to improve the sustainability of dairy goat farms in France

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Abstract. France is the largest producer of goat's milk in Europe with about 550 millions of liters collected. Since 2000, goat farms have moved towards intensive farming, largely increasing their need in purchased inputs, particularly feeds. To increase productivity, grazing has been gradually abandoned and indoor breeding has been developed. Resorting again to grazing could be a solution for improving the sustainability of goat farms, with a better control of feeding costs and a greater security of systems. In 2012, a system-experiment in Western France was designed at Inra to determine if this low-input solution would lead to high-performance farming systems. The system-experiment aimed at evaluating 2 independent farms of 60 Alpine goats differing in kidding period (February, GF or September, GS). Gastrointestinal parasitism was controlled every month by measuring strongyles' faecal egg excretion on faecal group samples. Between 2015-2018, annual mean grazing duration and average milk yield were higher for the GF farm (+ 37 days.year^{-1}, +25%; + 71 L.goat^{-1}.year^{-1}, +11%). However, the amount of concentrates and dehydrated feed was higher for GS farm (+14 kg.goat^{-1}.year^{-1}) despite a high proportion of herbage in the ration (68 ± 4%). Purchased feed costs were generally low (147 ±34 € per 1000 L), and higher for the GS farm (+ 47€ per 1000 L). This higher purchase cost had no consequences because the price of milk was higher for the GS farm (+ 56€ per 1000 L). Annual mean flock excretions of strongyles were low (178 ±233 eggs per gram of faeces), but varied highly after the period of the year. Increase in grazing of high value grasslands seems thus to be an interesting option to improve the sustainability of dairy goat systems in France, whatever the kidding period.

Keywords. Dairy goat – Grazing – Kidding period – Feeding cost – Sustainable.

Utilisation du pâturage selon la période de mise-bas pour améliorer la durabilité des systèmes d'élevages caprins en France

Résumé. *La France est le plus grand producteur de lait de chèvre en Europe avec environ 550 millions de litres collectés. Depuis les années 2000, les élevages de chèvres se sont intensifiés, augmentant largement leurs besoins en intrants achetés, notamment en aliments pour animaux. Pour augmenter la productivité, le pâturage a été progressivement abandonné et une conduite en bâtiment s'est développée. Une utilisation accrue du pâturage peut être une solution pour améliorer la durabilité des exploitations caprines avec un meilleur contrôle des coûts d'alimentation et une plus grande sécurité des systèmes. En 2012, l'Inra a mis en place une expérimentation système dans l'Ouest de la France pour évaluer des systèmes d'élevages caprins plus autonomes et durables. L'expérience-système visait à évaluer deux systèmes indépendants de 60 chèvres alpines différant par la période de mise-bas (en février, GF ou septembre, GS). Entre 2015 et 2018, la durée moyenne de pâturage et la production laitière moyenne étaient plus élevées pour le système GF (+ 37 jours/an, + 25 %; + 71 L/chèvre/an, + 11 %). Cependant, la quantité de concentrés et de déshydratés était légèrement supérieure pour le système GS (+ 14 kg/chèvre/an) malgré une part importante d'herbe dans la ration (68 ± 4 %) pour les deux systèmes. Les coûts d'alimentation étaient faibles (147 ± 34 €/1 000 L) mais toutefois plus élevés pour la ferme GS (+ 47 €/1 000 L). Ce coût d'achat plus élevé a eu peu de conséquences car le prix du lait était plus élevé pour le système GS (+ 56 €/1 000 L). Les chèvres des deux systèmes ont été infestées par des strongles gastro-intestinaux. Les niveaux moyens d'excrétions annuelles sont restés toutefois faibles (178 ± 233 œufs par gramme de fécès), mais les variations étaient fortes selon de la période de l'année. Augmenter le pâturage dans les prairies de bonne qualité constitue une solution intéressante pour améliorer la durabilité des élevages caprins en France, quelle que soit la période de mise-bas.*

Mots-clés. *Chèvre laitière – Pâturage – Période de mise-bas – Coût alimentaire – Durable.*

I – Introduction

Western France concentrates over half of the country's capacity in terms of dairy goat production (70% of national collection – Agreste, 2018). Between the years 2000 and 2010, many goat farms have gradually switched to intensive farming, thereby significantly increasing their need for purchased inputs. To increase productivity, grazing has been abandoned and the indoor breeding system has been adopted. Nowadays, feed self-sufficiency of dairy goat systems is only 55% (Bossis *et al.*, 2014) while that of dairy cow systems in the area reaches 88% (Brunschwig *et al.*, 2012). However, in a context of higher input costs, these systems become now unsustainable. Improvement in feeding self-sufficiency by a greater use of grazing is a major goal for dairy goat farms, so as to deal with the ups and downs of input costs and of climatic hazards, to improve the traceability of feed and to reduce the dependence on imported protein. Consumer's demand of goat cheese is high all year round, while the industry promotes off-season milk production by applying higher milk price in winter to smooth yearlong milk availability. However, a kidding period in September combined with grazing is unusual in France. The aim of this study was to evaluate, under controlled conditions, the benefits of grazing in dairy goat systems, in order to improve sustainability, for different kidding periods.

II – Material and methods

In 2013, the French Institute for Agricultural Research (Inra) built an experimental goat shed with a solar-heated air hay dryer to design more sustainable goat farming systems: the Patuchev platform. This device is aimed at assessing and proposing innovative goat farming systems in order to lead to low input and sustainable goat farming. This approach associates the research of economic, environmental and social performances in an effort to apply the principles of agroecology (Caillat *et al.*, 2012).

The experimental device is based on conception and long-term evaluation of three farmlets with about 60 French Alpine goats each: two grazing herds, one kidding at the end of the winter (February – GF farmlet) and the other one in autumn (September – GS Farmlet), and a herd fed hay indoors all year round and kidding in autumn (IS Farmlet). This study involved the 2 farmlets with grazing systems (GF and GS Farmlets). The area for each farmlet was set to 10.4 ha. This area was divided between temporary multi-specific grasslands (7.4 ha) and a cereal-protein crops mixture (3 ha).

For each farmlet, milk yield was recorded daily as well as protein and fat contents, while microbial flora and somatic cells were counted 3 times per month. Gastrointestinal parasitism was controlled every month after measuring strongyle faecal egg excretion on faecal group samples. The input and output flows were handled separately for each farmlet and recorded weekly to evaluate the economics results.

Data were recorded in the DIAPASON software (Institut de l'élevage, 2012). The study period was the same for the 2 farmlets. It began on September 1st of year N-1 and finished on August 31st of year N. A descriptive analysis of technical and economic results of each farmlet was carried out during the 2015-2018 period.

III – Results and discussion

1. Technical results

During the period considered, the number of dairy goats in lactation was higher for the farmlet with a kidding period in February (GF) (+9 dairy goats in average) but the proportion of primiparous goats was similar (30%). This difference could be attributed to specific fertility's difficulties of GS primiparous goats during the first lactation, which led to stopping their career before the second lactation.

Annual mean grazing duration and average milk yield were higher for the GF farm (+ 37 days.year^{-1}, +25%; + 71 L. goat^{-1}.year^{-1}, +11%). However, the amount of concentrates and dehydrates was higher for the goats with a kidding period in September (+14 kg.goat^{-1}.year^{-1}), despite a large, on average, herbage proportion in the ration (69 ± 6%). The annual mean flock excretions of strongyles were low (178 ± 233 eggs per gram of faeces in average) but varied widely according to the period of the year, particularly for the GF's goats (Table 1).

Table 1. Technical results according the kidding period

	February GF	September GS
Number of dairy goat	61 (± 6)	52 (± 10)
Primiparous (%)	29 (± 6)	31 (± 11)
Mean number of lactation	2.8 (± 1.7)	2.9 (± 2.0)
Milk yield and composition		
Raw milk yield (L/year)	709 (± 43)	638 (± 39)
Fat (g/L)	38.4 (± 1.0)	39.7 (± 1.0)
Protein (g/L)	33.8 (± 0.5)	35.0 (± 0.9)
Milk solids (kg/year)	53 (± 3)	50 (± 3)
Diet		
Concentrates (kg/year)	269 (± 33)	283(± 31)
Days of grazing (nb/year)	174 (± 21)	137 (± 18)
Nb days of grazing / duration of lactation (%)	62 (± 8)	50 (± 9)
Proportion of forages (%)	67 (± 2)	69 (± 6)
Annual FEC (EPG)	255 (± 271)	93 (± 119)

2. Economic results

The operating costs were always higher for the farmlet with a kidding period in September (+ 43% in average). Purchased feed costs were low for both farmlets (147 ± 34€ per 1000 L) but the breeding costs were much higher for the farmlet with a kidding period in September (+ 70€ per 1000 L). However, the financial consequences were low because the price of milk and other revenues were higher for the GS farmlet (+ 66€ per 1000 L) (Table 2).

The feeding self-sufficiency was similar and high for the 2 farmlets (79.5% on average).

Table 2. Economic results and feeding self-sufficiency according the kidding period

	February GF	September GS
Revenues (€ / 1000 L)		
Value of milk	678 (± 14)	734 (± 23)
Other revenues	127 (± 14)	137 (± 20)
Operating expenditures (€ /1000L)		
Purchased feeding costs	123 (± 13)	170 (± 30)
Breeding costs	186 (± 18)	256 (± 19)
Mechanization costs	134 (± 16)	199 (± 51)
Soil fertilization costs	26 (± 9)	38 (± 10)
Feeding self-sufficiency (%)	80 (± 5)	79 (± 7)

The higher operating costs for the GS farmlet can be explained by a lower milk yield and their standardization to 1000L of milk, but for equal milk yields this farmlet still had higher costs.

IV – Conclusion

A greater use of grazing is an important factor to improve the self-sufficiency and economic sustainability of dairy goat farms in France. Despite higher operating costs, associating grazing with a kidding period in September is an interesting option, since farm income is higher. However, it is still necessary to aim for a high production volume of milk solids (milk yield, fat and protein contents). Moreover, it appears important for this option to breed primiparous animals to ensure the transition to 2nd lactation and to limit the costs of replacement. Other technical solutions like long lactation periods for these goats or a later kidding date could be evaluated in future.

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Goat production systems in north Moroccan woodlands: forage production and use of silvopastoral resources

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Abstract. In northern Morocco, goats feed partly or totally in the woodlands. These forest rangelands currently undergo a huge pressure, related to climate changes and anthropic pressure. This study aimed to evaluate the pastoral potential of these woodlands and to investigate their use. We selected two forest rangelands (Beni Arouss and Derdara) where goat farming has been the dominant activity for decades. To estimate forage production (biomass), we used the method of the reference module. In the same period, interviews were carried out with goat herders. An average of ninety-six plant species was counted in each rangeland. The pastoral shrubs, mainly *Arbustus unedo, Cistus crispus, Cistus monspeliensis, Erica arborea, Lavandula stoechas* and *Pistacia lentiscus*, were the main species eaten by goats. For biomass, significant differences were noted according to season and sampling site, with a maximum forage production in spring of 3143 kg DM per hectare and 2905 kg DM per hectare, observed respectively in Beni Arouss and in Derdara. Furthermore, we identified degraded areas dominated by annual species together with species of low pastoral interest and thorny plants. During drought season, when the pastoral offer is limited, pruning of trees is performed during grazing. Due to climate changes and overgrazing, we expect that availability and quality of woodlands used for grazing will continue to decrease over the next decades. The reasonable use of pastures, including a reduction in grazing pressure, should be developed to ensure their sustainability.

Keywords. Northern Morocco – Goat – woodland – Biomass – Rangeland.

Systèmes de production caprine dans les forêts du nord du Maroc: production fourragère et utilisation des ressources sylvopastorales

Résumé. *Au nord du Maroc, les caprins tirent tout ou partie de leurs rations des forêts. Les parcours forestiers connaissent actuellement une forte pression, liée aux changements climatiques et à la pression anthropique. Cette étude visait à évaluer le potentiel pastoral de ces forêts pâturées et à étudier leur utilisation. Nous avons sélectionné pour l'étude deux pâturages forestiers (Beni Arouss et Derdara), où l'élevage de chèvres est pratiqué depuis des décennies. Pour estimer la production fourragère (biomasse), nous avons utilisé la méthode du module de référence. Durant la même période, nous avons mené des entretiens avec les éleveurs de chèvres. Quatre-vingt-seize espèces de plantes en moyenne ont été identifiées dans chaque parcours. Les arbustes pastoraux, principalement* Arbustus unedo, Cistus crispus, Cistus monspeliensis, Erica arborea, Lavandula stoechas *et* Pistacia lentiscus*, constituent la majeure partie du régime alimentaire des caprins. Pour la biomasse, des différences significatives ont été notées en fonction de la saison et des sites d'échantillonnage, avec une production fourragère maximale au printemps de 3143 kg MS/ha et de 2905 kg MS/ha, respectivement à Beni Arouss et Derdara. En outre, les recherches ont montré l'apparition de zones dégradées dominées par des espèces annuelles ainsi que par des espèces à faible intérêt pastoral et des espèces végétales épineuses. Pendant la saison de sécheresse, lorsque l'offre pastorale est limitée, et l'émondage des ligneux est effectué au moment du pâturage. En raison des changements climatiques et du surpâturage, nous nous attendons à ce que la disponibilité et la qualité des espaces boisées exploités pour le pâturage continue à diminuer au cours des prochaines décennies. L'utilisation raisonnable des pâturages, y compris via une réduction de la pression de pâturage, devrait être mise en oeuvre pour assurer leur durabilité.*

Mots-clés. *Nord du Maroc – Caprins – Forêt – Biomasse – Parcours.*

I – Introduction

In the Mediterranean basin, woodlands are normally mixtures of tree, shrub, and herbaceous species. Mediterranean forest rangelands are considered as the main forage resource for animal feeding. In addition, they provide goods and services for the local population and benefits for pasture productivity and biodiversity (Plieninger *et al*., 2015). During the last decades, forest rangelands have undergone profound changes, leading to a major forage imbalance between supply and demand (FAO, 2011).

Moroccan forest rangelands are traditionally an integral part of goat feeding systems and consequently of extensive livestock systems. In the northern part of Morocco, called also Rif mountain, the woodland is under pressure due to climate change, overgrazing and to to the misuse use of silvopastoral resources such as pruning (Chebli *et al*., 2018). In order to design and promote a sustainable and integrated development of forest rangelands, we need first an evaluation of the seasonal and annual forage availability and the determination of the current forest rangelands use. This study was conducted in two forest rangelands of northern Morocco exclusively grazed by goats. The aim was to assess their floristic composition, forage availability, and to investigate their modalities of use.

II – Materials and methods

The study was conducted in two forest rangelands called Beni Arouss (35°32' N, 5°57' W) and Derdara (35°28' N and 5°18' W), located in Tetouan and Chefchaouen provinces, respectively. The climate is Mediterranean, hyper-humid with cold winter and torrential rainfalls (1000-1400 mm), and warm summer. Temperature ranges from 3 to 14 °C in winter and from 18 to 38 °C in summer (Chebli *et al*., 2018).

The study was conducted over a period of nine months to assess the seasonal variation of forest rangelands qualitatively and quantitatively.

The qualitative evaluation of forest rangelands concerned floristic diversity. Plant identification was carried out directly in the field based on prior botanical knowledge. To identify plant local names, we relied on the survey with herders. In each sampling period, an herbarium was collected to determine the seasonal floristic composition. For the quantitative study, forage availability was assessed by determining the biomass of palatable species. Measurements were performed during three seasons: autumn, spring, and summer. Plant biomass was measured using the stratification method as described by Chebli *et al*. (2016). Each forest pasture was divided into four sites to control rangeland heterogeneity. Forty quadrats (10 quadrats/site) were installed in each forest rangelands. The size of the quadrats adopted for measurement of biomass was 40m² (4m x 10m) for shrubs and 1m² for the herbaceous layer. Several surveys were conducted with herders during the study period to gather details on the modalities of use of forest rangelands. Goat behavior was analyzed throughout direct observation as described by (Meuret *et al*.,1985). Data were analyzed using analysis of variance (ANOVA). Tukey-Kramer HSD test was used to perform the multiple comparisons for all pairs of means. Effects were regarded as significant at $p < 0.05$. The statistical procedures were performed using the SAS software.

III – Results and discussion

1. Floristic composition

Beni Arouss and Derdara are two forest rangelands characterized by an important number of pastoral plant species, among which many shrubs and trees. An average of ninety-six plant species was

counted in each site. Both forest rangelands contained three distinct vegetation groups: shrubs (*Arbutus unedo L., Calicotome villosa L., Cistus crispus L., Cistus monspeliensis* L.*, Cistus salviifolius* L.*, Erica arborea* L.*, Lavandula stoechas* L.*, Myrtus communis* L.*, Phillyrea media* L.*,* and *Pistacia lentiscus* L.*),* trees *(Quercus ilex* L.*, Quercus suber* L.*,* and *Olea europaea* L.*),* and herbaceous plants. Woody plants made up more than 90% of the forage selected by goats, according to their seasonal availability. Herders confirmed the appearance of unpalatable species in the overgrazed sites, such as site 4 in Beni Arouss, and site 3 and 4 in Derdara. Four unpalatable species were identified, namely: *Anagallis arvensis* L, *Arisarum vulgare* (Targioni-Tozzetti), *Coriaria myrtifolia* L.*, Daphne gnidium* L.*,* and *Ranunculus sardous* (Crantz). As reported by Chebli al. (2016) who studied similar forest rangelands, the presence of unpalatable species might be explained mainly by overgrazing.

2. Forage production

Forage production differed significantly between sampling sites, for each forest rangeland ($P<0.05$). The average forage production recorded was 2327 kg DM/ha and 2106 kg DM/ha, respectively in Beni Arouss and Derdara (Fig. 1). Regardless of the season, site 1 in each rangeland displayed a significantly higher forage production. This could be explained by a high vegetation density in site 1, dominated mainly by shrubs and trees, which limited goat movements and consequently reduced grazing pressure. Site 4 of each rangeland was considered as an intensively grazed area. In this site, dominated by small shrubs and herbaceous plants, we recorded low forage production and low regeneration of palatable species.

Season affected significantly forage production ($P<0.05$), with a higher forage production recorded in Spring both in Beni Arouss (3143 kg DM/ha) and in Derdara (2905 kg DM/ha) (Fig. 1). This might be explained by favorable growing conditions due to the precipitation recorded in winter and early spring.

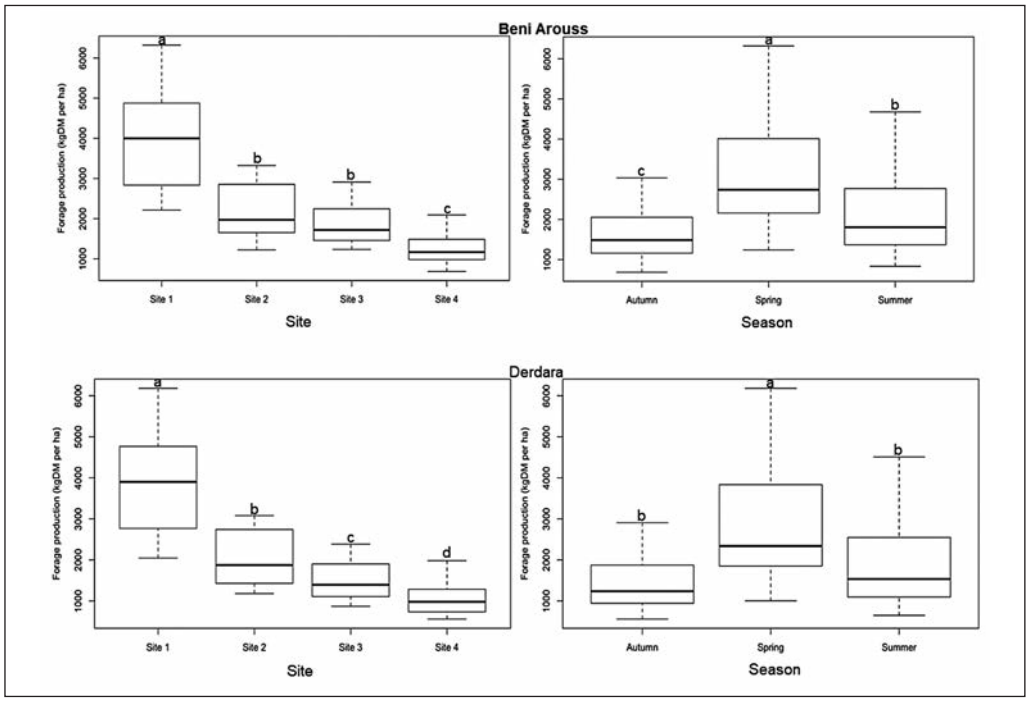

Fig. 1. Sampling site and season effects on forage production in Beni Arouss and Derdara. a-c Different letters indicate that values are significantly different ($p<0.05$).

3. Forest rangeland use

In northern Morocco, small forests are mainly used as a land reserve for agricultural activities, and large forests are used for grazing and fuelwood harvesting (Chebli *et al*., 2018).

Goats are herded by the breeder himself or by a younger family member. Grazing is practiced throughout the year (9 to 12 hours per day), except during the rainy periods (mid-autumn to mid-winter) where grazing time is reduced to only 2 to 3 hours per day. During the winter, access to pasture becomes difficult, which explains the pruning practice in order to reduce the burden of forage supplementation. The spatial distribution of goats is not determined by specific grazing management rules. Goats are concentrated for a long time on the same pasture conducting to overgrazing and therefore to the appearance of low palatable species and to the disappearance of palatable species. According to our observations and survey with herders, goats' itinerary and diet depends on the season and on forage availability. In spring, goats consume herbaceous species and shrubs: *C. crispus., C. monspeliensis, C. salviifolius, A. unedo* and *L. stoechas*. During the summer, goats' diet is composed by *A. unedo, E. arborea,* and even tree branches of *Q. ilex, Q. suber* and *O. europaea*. In spring, 62% of animal activity is devoted to grazing, against 69% in summer. The short duration of grazing in spring compared to summer can be explained by the high forage availability, coinciding with the vegetative peak of pastoral species.

IV – Conclusions

In northern Morocco, forest rangelands represent the most important feed source for goats. Forage availability varied according to season and grazing intensity. The continuous use of pastoral resources and the lack of pasture management has considerably reduced the palatable pasture species and has allowed the appearance of less palatable species. Management actions and use of silvopastoral resources, including a reduction in grazing pressure, should be developed to ensure a better productivity and the sustainability of these forest resources.

Acknowledgments

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Access time to pasture has an effect on goats' milk production and body condition

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Abstract. Increasing the proportion of grass in rations, without decreasing the total intake, is nowadays a key aspect of goat feeding. The objective is thereby to maintain or even improve individual performance, keep goats in good metabolic health and ensure an efficient utilization of forage resources. Various studies focusing on daily access times to pasture have been conducted between 2015 and 2018 in two experimental stations, including the 'Station du Pradel' in the South East of France (Ardèche, 07). The experiment reported here lasted 49 days, during spring 2018. The objective was to compare a continuous access to pasture of 7h vs 10h per day. The animals were separated in homogeneous groups of 59 goats (46 multiparous and 13 primiparous) and were milked once a day. Access time had significant effect on milk production and bodyweight. Goats that were grazed outdoors for 10h produced 260g more milk (+8%) and lost only 2.8kg during the experimental period, vs 4.0kg for the 7h-group. This can be explained by a difference in the time spent ingesting grass at pasture: 5h30 for the 7h-group, vs 6h15 for the 10h-group (method Lifecorder). The proportion of time spent ingesting grass was higher for the 7h-group (73.7% of the time outside) than for the 10h-group (60.5%). Also, primiparous goats spent more time (+10%, whatever the group) ingesting grass than multiparous goats. These results are slightly different from those obtained in western France.

Keywords. Feeding – Grazing – Dairy goats.

Le temps d'accès au pâturage a un effet sur la production laitière et l'état corporel des chèvres

Résumé. *Augmenter la proportion d'herbe dans les rations, sans diminuer l'ingestion, est aujourd'hui un défi de l'alimentation des chèvres. Le but est ainsi de maintenir voire d'augmenter les performances individuelles, de garantir une bonne santé métabolique des chèvres et d'assurer une bonne valorisation nutritionnelle de la ressource fourragère. Plusieurs études sur le temps d'accès au pâturage ont été conduites entre 2015 et 2018 sur deux stations expérimentales, dont la station du Pradel dans le Sud-Est de la France (Ardèche, 07). L'essai a duré 49 jours au printemps 2018 et a permis de comparer des accès continus au pâturage de 7h et 10h par jour. Les animaux ont été séparés en deux groupes homogènes de 59 chèvres (46 multipares et 13 primipares) traites une fois par jour. Le temps d'accès au pâturage a eu un effet significatif sur la production laitière et l'état corporel. Les chèvres qui étaient à l'extérieur 10h par jour ont produit 260g de lait en plus (+8%) et n'ont perdu que 2,8kg de poids vif contre 4,0kg pour le groupe qui sortait 7h. Cette différence peut être expliquée par le temps que les chèvres ont passé à ingérer lorsqu'elles étaient au pâturage. En effet, le groupe qui pâturait 7h a passé 5h30 à ingérer de l'herbe contre 6h15 pour le groupe qui sortait pendant 10h (méthode Lifecorder). La proportion de temps passé à ingérer était supérieure pour le groupe 7h (73,7% de son temps passé à l'extérieur) par rapport au groupe 10h (60,5%). Enfin, les primipares ont passé plus de temps à ingérer de l'herbe au pâturage (+10%, quel que soit le groupe). Tous les résultats présentés sont légèrement différents de ceux obtenus dans l'Ouest de la France.*

Mots-clés. *Alimentation – Pâturage – Chèvres laitières.*

I – Introduction

Goat production is increasing worldwide, with global livestock raising from 750 million heads in 2000 to 1034 million heads in 2017. Meanwhile, goat milk production evolved from 12.7 million of tons to 18.7 million of tons on the same period, according to the FAO statistics (2017).

Unfortunately, goat production is also the less self-sufficient herbivorous production in terms of feed. The principal lever to improve self-sufficiency is to use more grass, in all forms, in the ration (Legarto & Leclerc, 2007).

The goal of the experiment reported here was to study the effect of access time to pasture on goats' performances, feeding behaviour and identify the potential effect of this parameter on the organization of a working day.

II – Materials and methods

The experiment took place during spring 2018, from the 9th of April to the 28th of May.

1. Animals

The Pradel experimental station is located in the South East of France (Ardèche, 07). After a 4-week pre-experimental period, 118 Alpine goats were separated in two homogenous groups of 59 (46 multiparous and 13 primiparous goats). At the beginning of the experiment, the two groups had the same milk production, fat and protein rates, body condition, body weight and lactation stage. Goats were milked once a day at 6.00, then fed the same amount of corn and of an industrial concentrate. A rotational grazing system was used on the farm. The total surface used for the trial was 7.78 ha divided in 12 plots, of which 10 were ryegrass/cocksfoot or cocksfoot/brome grass mixtures and 2 were pure white clover. The 7h-group was out from 9.00 to 16.00 and the 10h-group from 9.30 to 19.30. The experiment lasted for 7 weeks and goats were grazing every day when the meteorological conditions were good enough.

2. Measurements

Milk controls were performed every week and individual milk production was recorded. Total production and production of each group were also measured daily. Body weight and body condition score (BCS) were recorded once in the middle of the experiment and once at the end.

Feeding behaviour was evaluated at pasture with the Lifecorder® device, a portable accelerometer which measures the vertical movement of the animal's head and determines when it is grazing. The method was tested and validated on cows (Delagarde and Lamberton, 2015) then on goats (Charpentier, 2015; Cornut, 2016). In each group, 13 goats were equipped with the Lifecorder® device. The monitoring of grazed paddocks was done daily and entry and exit heights were recorded for each new plot using a plate meter (30 measures/ha).

Four periods were defined to take into account the changes in supplementation (based on the availability of grass and the corn/concentrate ratio). Periods 2 to 4 were used for statistical analyses. Period 1 was not analysed because the weather was too bad for the goats to go outside.

3. Statistical analysis

Individual performances were analysed with a covariance analysis (ANCOVA) with fixed effects of treatment and period, a random effect due to the individual, the effect of the interaction between treatment and time and the initial performance as a covariate. For feeding behaviour, the effect of parity was also tested.

III – Results

1. Milk production

Treatment, period and interaction treatment*period had a significant effect on the total milk production (P=0.0003, P<0.0001 and P=0.0247 respectively), in periods 2 and 3. Over the experiment, goats on the 10h-group produced 260g more milk per day than the 7h-group. Details about the different periods are available in Table 1.

The treatment didn't have a remarkable effect on milk quality indicators.

Table 1. Mean individual milk productions global and per period

	Period 2		Period 3		Period 4		Total experiment
	Milk production (kg/d/goat)	P-value	Milk production (kg/d/goat)	P-value	Milk production (kg/d/goat)	P-value	Milk production (kg/d/goat)
7h-group n = 57	3.60* (±0.74)	0.0003	3.24* (±0.65)	0.0004	3.96 (±0.76)	0.1284	3.60* (±0.77)
10h-group n = 57	3.92* (±0.88)		3.55* (±0.81)		4.10 (±0.93)		3.86* (±0.90)

*Significant result, P-value < 0.05.

2. Body weight and body condition

Access time to pasture also had a significant effect on body weight (P=0.01151), but not on body condition. The mean loss of body weight for the 10h-group was 2.76kg vs 3.95kg for the 7h-group, as shown in Table 2.

Table 2. Mean individual variation of body weight and BCS

	Body weight (kg)	BCS (lumbar zone)	BCS (sternal zone)
7h-group n = 57	- 3.95*	- 0.10	- 0.14
10h-group n = 57	- 2.76*	- 0.06	- 0.12

*Significant result, P-value < 0.05.

3. Feeding behaviour

Treatment, period and parity all had a significant effect on feeding behaviour (P=0.0005, P<0.0001 and P=0.0254 respectively). As could be expected given the results about milk production, the 10h-group spent more time ingesting grass while outside (and thus had a higher total intake) than the 7h-group. The 7h-group spent 5h30 of its time ingesting grass vs 6h15 for the 10h-group. However, proportionally, the 10h-group spent less of its available time ingesting grass at pasture (60.5% of the time outside) than the 7h-group (73.7%). In the two groups, primiparous goats spent more time ingesting grass (+10% of available time) than multiparous goats, probably due to a lower intake rate (Fig. 1).

III – Discussion

An access time to pasture of 10 hours instead of 7 hours lead to a higher milk production (+260g/d/goat). This result differs from Charpentier (2018) where an access time of 8 hours instead of 11 hours didn't have a significant impact on milk production. Goats of the 11h-group produced 0.025kg more milk per extra hour outside whereas in our study in the 10h-group they produced 0.087kg more per extra hour, which is significantly different from the 7h-group.

To explain the difference, the most likely hypothesis is that goats from the 10h-group consumed more grass and mobilized less their body reserves than goats on the other group; they produced more milk and lost less body weight.

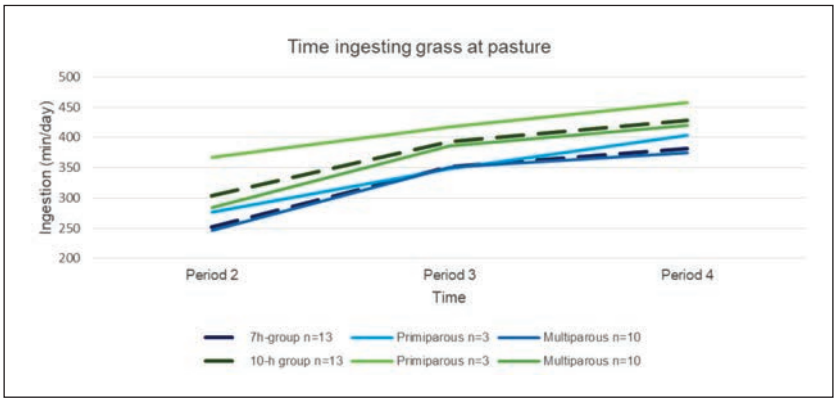

Fig. 1. Time ingesting grass at pasture.

III – Conclusion

Access time to pasture had a significant effect on milk production and bodyweight. Goats proportionally spend more time grazing when their access time to pasture was lower. In this study, given the level of supplementation, an access time of 7h might have not been sufficient to ingest enough grass to express the full dairy potential. Conversely, a 10-hour access to pasture allowed the goats to consume more grass and produce more milk.

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Feeding practices in sheep stockbreeding in the Algerian steppe (M'Sila region): Current situation and prospects for improvement

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Abstract. The Algerian steppe covers 20 million hectares and is located between the isohyets of 100 and 400 mm/year. It is home to 17 million sheep (MADRP, 2016). For the past 50 years, it has undergone many changes and transformations resulting from the stockbreeding management that contributed to a decline in forage productivity and in the surface area of steppe pastures. Therefore, the steppe pasture covers only 30 to 40% of the animal's feed requirements. To face this situation, stockbreeders are adopting various feeding strategies. Our objective was to assess the feeding practices adopted by the herders in M'Sila region. This region has 1 million ha of rangelands and hosts 1.63 million sheep heads (DSA, 2016). One hundred herders, from the different breeding systems and different pastoral areas, were investigated by technical-organizational approaches. The analysis of field interviews revealed the presence of two feeding calendars, involving different feed sources (concentrate feeds, cultivated forages, and cereal co-products). Although the supplementation with concentrate feeds is a common practice to meet animal needs (about 40% of ration), there are new feeding trends based on the direct consumption of green fodder (barley, oat and alfalfa). The choice of feeding strategies depends on the socio-economic and agricultural considerations of each herder (herd size, financial capacity, farming practice, income diversification, etc.).

Keywords*:* Agropastoral stockbreeding systems – Steppe rangelands – M'Sila Algeria – Feeding calendar – Feed supplement – Prospects.

Pratiques d'alimentation dans les élevages ovins en steppe algérienne (Région de M'Sila) : Réalité et perspectives d'amélioration

Résumé. *Le territoire steppique algérien de 20 millions d'hectares, se délimite entre les isohyètes de 100 et 400 mm/an. Il abrite 17 millions d'ovins (MADRP, 2016). Depuis 50 ans il a connu de nombreuses évolutions et transformations engendrant des conduites d'élevage qui contribuent à une baisse de la productivité fourragère et de la surface des pâturages steppiques. Ainsi, la pâture steppique couvre seulement 30 à 40% des besoins alimentaires des animaux. Pour faire face à cette situation, les éleveurs adoptent diverses stratégies alimentaires. Notre questionnement s'intéresse aux pratiques et modalités d'alimentation adoptées par les éleveurs de la région de M'Sila. Cette région compte 1 million d'ha de parcours et 1,63 million d'ovins (DSA, 2016). Cent éleveurs des différents systèmes d'élevage et de différentes zones pastorales ont été enquêtés par approches technico-organisationnelles. L'analyse des données d'entretien révèle la présence de deux calendriers alimentaires, avec différentes ressources fourragères (aliments concentrés, fourrages cultivés, et sous-produits de la céréaliculture). Bien que l'apport en aliments concentrés relève d'une pratique récurrente pour satisfaire les besoins des animaux (soit environ 40% de la ration), il existe de nouvelles tendances alimentaires basées sur les fourrages cultivés et consommés généralement en vert (orge, avoine et luzerne). Le choix des stratégies alimentaires dépend de considérations socio-économiques et agricoles propres à chaque éleveur (taille de troupeau, capacité financière, pratique de l'agriculture, diversification des revenus, etc.).*

Mots-clés. *Systèmes d'élevage agropastoraux – Parcours steppiques – M'Sila Algérie – Calendrier alimentaire – Complément alimentaire – Perspectives.*

I – Introduction

The Algerian steppe territory (located between isohyets 100 and 400 mm) extends over 20 million hectares (Aidoud et *al.*, 2006). It hosts mainly sheep pastoral activities (Nedjraoui, 2004) with 17 million sheep heads (62% of the national sheep flock (MADRP, 2016) and 13 million hectares of grazing land (Aidoud *et al*., 2006). Pastoral activities has allowed to live until now the steppe population (Bencherif, 2018).

However, the rangelands which were the main feed source for the sheep flocks suffered from a severe degradation. Nowadays 80% of rangelands are declared degraded (HCDS, 2010). Several factors have contributed to the impoverishment of rangelands, the most significant being: the population growth, the increase in the number and size of sheep flocks, cultivation of rangelands, a new habitat's mode, socio-cultural changes, and recurrent and extended droughts.

Confronted to the scarcity of natural fodder, herders are in a permanent uncertainty about how to ensure enough feed for their animals. Therefore, stockbreeders are adopting different strategies. Our study aimed to define and analyse the feeding strategies of sheep herders and to estimate diet composition across the year. A question arises as to whether these strategies are short-term opportunistic practices or can be resilient in the long term.

II – Materials and methods

The methodology adopted in the current study is based on technical and organizational interviews. We conducted interviews with a sample of 100 stockbreeders representing various existing livestock systems and different pastoral areas of the Wilaya (Department). In addition to interviews, the collection of statistics from agricultural and grazing managements services was necessary to complement the field data.

The M'Sila region was chosen for the study on criteria related to animal numbers and pastoral areas (1.63 million sheep heads, 1 million hectare of rangelands) (DSA, 2016).

III – Results and discussion

1. Breeders' classes

The most relevant classification criterion is the size of the sheep flock owned. We classified herders into four groups (Table 1). Stockbreeders whose flock's size was less or equal to 500 heads, i.e. classes I, II and III represent 91% of the whole sample, and own 61% of the total sheep stock. On the other hand, class IV (flock size between 501 and 1950 heads) although representing only 9% of the breeders, owns 39% of the total sheep stock.

In other words three fifth (3/5) of the sheep are owned by "small owners" and "middle owners " (Classes I, II and III), while the breeders described as "big owners" (class IV) have two fifths (2/5) of the sheep stock.

Table 1. Classification of breeders interviewed according to the size of their sheep flocks

Classes	No. of herders	(%)	Total sheep	(%)
Class I (≤ to100 heads)	17	17%	1 283	4%
Class II (101-200 head)	35	35%	5 436	18%
Class III (201-500 head)	39	39%	11 815	39%
Class IV (501-1950 heads)	9	9%	11 813	39%
Total	100	100%	30,347	100%

2. Feeding calendars

The feeding calendar is a simple schematic representation of the utiliation frequencies of different feed resources across the year. The analysis of our interviews put forward two different feeding calendars:

- The first concerns breeders of the first three classes (I, II and III), who share the same utilisation frequencies of the different feed resources (Fig. 1).
- The second calendar concerns breeders of class IV (Fig. 2) and is characterised by a different utilisation frequencies of feed resources when compared to the previous classes, especially:
  - A limited reliance on rangelands: 6 months of use against 12 months for calendar(1);
  - An insignificant use of hay and straw (does not even appear in the calendar);
  - Higher use of fallows, which do not appear in calendar (1).

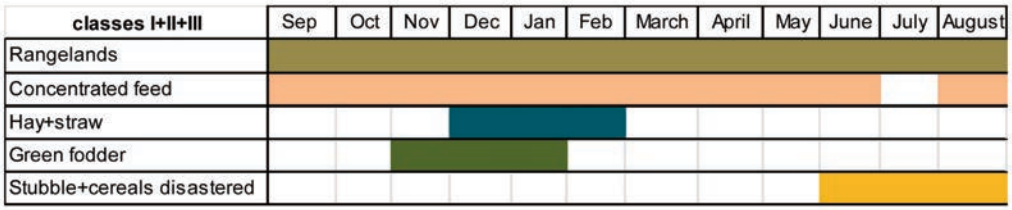

Fig. 1. Feeding calendar (1) of breeders classes I, II and III.

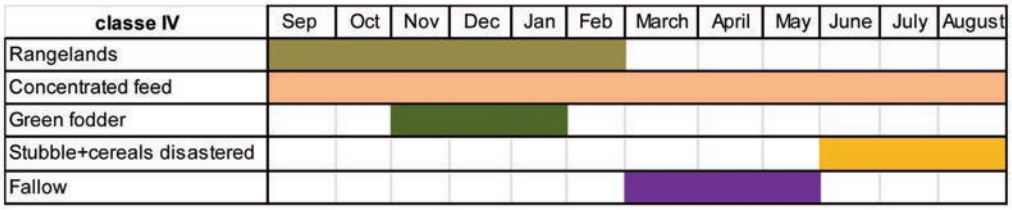

Fig. 2. Feeding calendar (2) of breeders class IV.

3. Diet composition

The calculation of diet composition shows the contribution of each feed resource to the satisfaction of flock's feed requiremnts. To estimate diet composition for the 100 herders along the year 2018 (year of the interviews), we performed individual calculations of diet composition for each breeder. We used the quantities and surfaces of the different feed resources used by the herders, andtheir estimated energy content expressed as forage units (UF). The reference values used for our feed calculations are summarized in Table 2. Furthermore, the contribution of rangeland biomass in the diet was calculated as the difference between total herd requirements and the energy provided by the other feed sources. Discussions with herders allowed us to approximate feed rations, under the hypothesis that the animal's needs are fully met.

The estimation of animal's requirements was achieved by the conversion factors proposed by Moskal (1983). These coefficients were adapted to the characteristics of the Algerian flocks. Converting heard's numbers into livestock units then UF allowed to homogenize the needs of animals

and feed intake. Additional requirements, accounting for grazing expenses, were included. Thus, the requirements were increased by 20% for the herders who did not use rangelands, and by 50% for the herders who used rangelands (CIRAD, 2002).

Table 2. Values of different feed resources

Type of feed	Nutritional value (UF / Unit)	Type of feed	Nutritional value (UF / Unit)
Barley[1]	0.94 UF / kg crude material	Stubble[3]	300 UF / ha
Wheat bran[1]	0.74 UF / kg crude material	Disastered cereals[3]	500 UF / ha
Soft wheat[1]	1.05 UF / kg crude material	Fallow[3]	325 UF / ha
But[1]	1.09 UF / kg crude material	Straw and hay[3]	UF 0.33 / Kg, 25Kg / haystack
Barley green[2]	1836 UF / ha		
Oats green[2]	3832 UF / ha		
Alfalfa green[2]	1743 UF / ha 1st cycle		
	1581 UF / ha 2nd cycle		
	1625 UF / ha 3rd cycle		
	1099 UF / ha 4th cycle		

[1](INRA (Fr), 2018) (our calculations); [2](Kerbaa, 1980); [3](CIZ / SYFEL, 2004).

There was a similarity in diet composition between herders of feeding calendars 1 and 2. This resemblance in dietary intake may be explained by the low contribution of the resources making the difference between both calendars (hay, straw, and fallow). The contributions of feeds to the total requirements of livestock are presented in Table 3.

Table 3. Contributions of feeds in livestock diets

	Intake (UF)	Percentage
Concentrated feeds	4,220,511	39.81%
Rangelands	2,923,933	27.58%
Green fodder (barley, oat, alfalfa)	1,802,878	17.00%
Stubble and disastered cereals	1,162,000	10.96%
Hay and straw	321,255	3.03%
Fallow	171,275	1.62%
Need's total	10,601,852	100%

Concentrated feeds make the highest contribution to the diet (39.81%); they constitute the basis of feeding in current stockbreeding systems. This confirms the current reality of the steppe, pointed out by scientists, with the transition from grass-based to concentrated-based feeding systems (Senoussi *et al.*, 2014). The concentrate feeds become the basic ration, and rangelands become supplements (Aidoud *et al*., 2006). This feeding mode based on concentrate feeds has limits. A technical limitation is the physiology of the animal : sheep are ruminants that need fiber in their diet. An economical limitation is the cost of sheep meat production (about 10€/ kg) which is too high and uncompetitive in front of international sheep meats (hence the heavy customs taxes on the import of animals).

The rangelands that used to be the main feed source for animals in the past, currently contribute only by 27.58% of the ration; this resulted from their severe degradation, caused mainly by overstoking (Senoussi, 2014). However, we identified new feeding practices adopted by herders to fill the fodder deficit, and especially forage crops (barley, oat, alfalfa) used in green and covering 17% of animal needs.

Other forage resources represent a significant part of the animals' diet (10.96%). They are mainly stubble and disastered cereals (cereals grown without irrigation and grazed on foot when yields are low). The remaining needs are covered by hay, straw and fallow land (4.65%).

While the overall analysis shows that the intake of concentrate feeds represents the main part of the animal diet, more refined analyzes suggest a diversity of strategies. We notice that :

- 17% of herders cover more than 50% of the animal's requirements with concentrate feeds (it can go up to 91%);
- 12% of herders are still relying on range vegetation, which covers between 50% and 80% of the diet;
- 12% of herders cover more than half of the animal's requirements (up to 80%) with green fodder, mainly barley and to a less extent oat and alfalfa, which are grown in irrigated conditions.

IV – Conclusion

Feeding calendars adopted by breeders reflect the importance to rely on alternative feed resources, to rehabilitate rangelands and to reduce the use of expensive concentrate feeds. However, herders react in an individual way, each according to its material and financial capacity. In the current conditions, the stockbreeding systems are vulnerable and feed shortage is prevailing. It should also be noted that at present herders have no intention to preserve the rangelands, hence the need to establish an integrated development strategy for environment, agriculture and livestock, and even other adjacent economic activities (crafts, agro-industrial processing, etc.).

It is recommended to establish a shared vision of development so that the development strategies can implement various integrated options (e.g. rehabilitation steppe rangelands, water management, forage promotion programs).

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Main plant species grazed by goats in two types of rangelands in Algeria: Mountainous *vs* Saharan

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Abstract. The objective of this study was to compare the pasture use and to evaluate the diversity of plant species grazed by goats in two different ecosystems: mountainous *vs* Saharan range. For this, a questionnaire survey was conducted among 100 farmers in Tizi-Ouzou (mountainous region) and another 100 in Bechar (Saharan region) during the same period (15 March-17 May). In Tizi-Ouzou, the goat's diet is almost (98%) based on grazing + supplement to the trough while in Bechar this practice is noted in 85% of the farms. In Tizi-Ouzou, grazing takes place largely on the forest rangelands, maquis, natural meadows and fallows while in Bechar the goats graze especially in the ergs, regs and beds of Wadis. The main grazed plant species in the Tizi-Ouzou region are: *Rosa sempervirens, Phillyrea angustifolia, Myrtus communis, Asphodelus microcarpus, Sinapis arvensis, Hedysarum flexuosum, Pistacia lentiscus, Calycotum spinosa* or *Cytisus spinosus, Rubus fruticosus, Inula viscosa* or *Dittrichia viscosa, Erica arborea* and *Lavandula stoechas*. In Bechar, on the other hand, goats graze mainly: *Cotula cinerea, Panicum turgidum, Stipagrostis pungens, Diplotaxis harra, Euphorbia guyoniana, Atriplex halimus, Tamarix gallica, Suaeda mollis, Artemisia herba alba, Zizyphus lotus, Helianthemum lippii, Retama retam, Moltkiopsis ciliata* and *Erodium triangulare*. Pasture makes most of the goat's diet in both regions. We observed a rich biodiversity of grazing species in the Saharan range, equal or superior to that of the mountainous region in this study.

Keywords. Goats – Feed – Rangelands – Pastoral species.

Principales espèces végétales pâturées par les caprins dans deux types de parcours en Algérie: montagneux* vs *Saharien

Résumé. *L'objectif de cette étude était de comparer le mode d'utilisation du pâturage et d'évaluer la diversité des espèces végétales pâturées par les caprins dans deux différents écosystèmes : parcours montagneux* vs *parcours sahariens. Pour cela, une enquête par questionnaire a été réalisée auprès de 100 éleveurs à Tizi-Ouzou (région montagneuse) et 100 autres à Bechar (région saharienne) durant la même période (15 mars-17 mai). A Tizi-Ouzou, l'alimentation des caprins est quasiment (98%) basée sur le pâturage + complément à l'auge alors qu'à Bechar cette pratique est relevée dans 85% des élevages. A Tizi-Ouzou, le pâturage a lieu en grande partie sur les parcours forestiers, maquis, prairies naturelles et jachères alors qu'à Béchar les chèvres pâturent surtout dans les ergs, regs et lits d'Oueds. Les principales espèces végétales pâturées dans la région de Tizi-Ouzou sont :* Rosa sempervirens, Phillyrea angustifolia, Myrtus communis, Asphodelus microcarpus, Sinapis arvensis, Hedysarum flexuosum, Pistacia lentiscus, Calycotum spinosa *ou* Cytisus spinosus, Rubus fruticosus, Inula viscosa *ou* Dittrichia viscosa, Erica arborea *et* Lavandula stoechas. *Par contre, à Bechar, les caprins pâturent surtout :* Cotula cinerea, Panicum turgidum, Stipagrostis pungens, Diplotaxis harra, Euphorbia guyoniana, Atriplex halimus, Tamarix gallica, Suaeda mollis, Artemisia herba alba, Zizyphus lotus, Helianthemum lippii, Retama retam, Moltkiopsis ciliata *et* Erodium triangulare*. Le pâturage couvre l'essentiel de l'alimentation des caprins dans les deux régions. Nous avons observe une riche biodiversité d'espèces pâturées dans les parcours sahariens, égale ou supérieure à celle de la région montagneuse considérée dans cette étude.*

Mots-clés. *Caprins – Alimentation – Parcours – Espèces pastorales.*

I – Introduction

Widely distributed throughout the world, goats are found especially in the harsh environments of the planet. Adaptation characteristics such as foraging behaviour, efficient use of feed and, to some extent, tolerance to diseases predispose them to take advantage of natural resources generally disregarded by other domestic ruminants.

The Algerian goat herd (5,007,894 heads according to FAO, 2017) is characterized by its adaptation to the climatic conditions of the country, and is concentrated mainly in the mountains, the rangelands of the Arid and Semi-arid Zones and the Saharan region. From an economic point of view, goats contributes to the income and the cover of milk and meat requirements of a large portion of the rural population.

In Algeria, several studies have been devoted to the characterization of goat farms in the mountainous regions of Tizi-Ouzou (Kadi *et al.,* 2014, 2016; Mouhous *et al.,* 2016, 2017). Those concerning the Sharian regions are rare (Kadi *et al.,* 2017; Guermah *et al.,* 2018).

As elsewhere in the world (Goetsch *et al.,* 2010), goat feeding in Algeria is based mostly on the use of rangelands throughout the year, whether in mountain areas (Kadi *et al.,* 2016; Mouhous *et al.,* 2016) or in Saharian zones (Kadi *et al.,* 2017). Therefore, the objective assigned to this study was to compare the pasture use and to evaluate the diversity of plant species grazed by goats in two different ecosystems: mountainous *vs* Saharan range.

II – Materials and methods

1. Description of study areas

Tizi-Ouzou (see official website http://wilaya-tiziouzou.dz/) is located on the central coast of Algeria and characterized by an 80% mountainous relief, an average altitude of 800 m, a predominantly rural population (63%) and a Mediterranean climate: wet and cold in winter and dry and hot in summer. Nearly half the area is occupied by natural vegetation. The region is described in a previous work by Kadi *et al*. (2014).

With an area of nearly 162 000 Km² (ANDI, 2013) and 1150 km away from the capital Algiers, Bechar is the largest *wilaya* –district– in southwestern Algeria. It is characterized by five main reliefs: the mountains (bare and sometimes high), the *wadis* (six in number), the valleys (the main ones are Zouzfana, Guir Saoura), the regs (vast rocky expanses) and the *ergs* (massive dunes up to 300 m high). The *wilaya* of *Bechar* is characterized by a desert type continental climate. There are two types of zones (ANDI, 2013). The transition zone is very hot in summer (+ 45 ° C) and cold in winter (2 ° to 3 ° C) with rainfall of about 60 mm / year and frequent and often violent sandstorms (100 km / h). The desert zone is characterized by rainfall around 40 mm / year and very frequent sandstorms. According to DSA (2016), the Bechar wilaya is characterized by a total agricultural area of nearly 1.5 million ha of which only 2.5% (35000 ha) is arable. The rest is the pasture and rangelands. In the livestock sector, goats (with nearly 53 000 heads) are second after sheep (220 000 heads), before camels (17 000 heads) and cattle (2600 heads).

2. Methodology

A questionnaire survey was carried out among 100 randomly chosen breeders in Tizi-Ouzou (mountainous region) and another 100 in Bechar (Saharan region) during the same period (15 March-17 May). A preliminary survey was conducted using a structured questionnaire as a basis for discussions with farmers. This questionnaire was structured in several sections including the identification of the farm, the situation and the socio-economic profile of the farmer, the management of livestock in general and of feeding in particular, including pastoral species. To complete the information collected through the questionnaires, interviews were conducted with all farmers

in both regions. Beforehand, the collection of information on the location of farms was carried out through direct contacts with agricultural subdivisions, veterinarians, goat milk collection centres and dairies. The data collected, after tabulation of the questionnaires, was coded and recorded in a database designed with Microsoft Excel® 2013 software. The data presented here concern the feeding aspects. A sample of farms was constituted to be representative of the goat sector diversity in the two regions according to Kadi *et al.* (2016 and 2017).

Descriptive statistics (means, standard deviations and proportions) were calculated for the feeding parameters. Grazed plant species were identified according to the breeders by their common name in Amazigh language in Tizi-Ouzou and Arabic in *Bechar* and then identified by their scientific name according to the literature in the field.

III – Results and discussion

In Tizi-Ouzou, the goat's diet was almost totally (98%) based on grazing + supplement to the trough while in Bechar this practice was noted in 85% of the farms. In Tizi-Ouzou, grazing takes place mainly on forest rangelands, maquis, natural meadows and fallows while in *Bechar* the goats graze especially in the *ergs, regs* and beds of *wadis* (Table 1).

Table 1. Goat feed calendar at the level of the two wilayas

Month		Jan.	Febr.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rangelands	Tizi-Ouzou	++	++	+	+	++	++	++	++	++	++	++	++
	Bechar	+	+	+	+	+	+	+	+	+	+	+	+
Cultivated fodder	Tizi-Ouzou	+	+	++	++	++							
	Bechar												
Hay	Tizi-Ouzou	++	+								+	++	++
	Bechar	+	+				+	+	+	+	+	+	+
Stubble	Tizi-Ouzou							++	++				
	Bechar												
oncentrated feed	Tizi-Ouzou	++	++	+	+	++	++	++	++	++	++	++	++
	Bechar	++	++	+	+	+	++	++	++	++	+	+	++

Degree of use: ++ intense; + moderate.

During all the year, the main species grazed in the mountainous region in Tizi-Ouzou are thirteen (Table 2).

Table 2. Main grazed plant species in Tizi-Ouzou (mountainous region)

Scientific name	Tamazigh name
Asphodelus microcarpus	*Avarwaq*
Cytisus spinosus	*Ouzou*
Dittrichia viscosa	*Amaguer Aman*
Erica arborca	*Akhelendj*
Hedysarum flexuosum	*Tasula*
Inula viscosa	*Imidek*
Lavandula stœchas	*Amezir*
Myrtus communis	*Arihan*
Pistacia lentiscus	*Imidek*
Phillyrea angustifolia	*Tametwala*
Rosa sempervirens	*Ti'fart*
Rubus fruticosus	*Anajel*
Sinapis arvensis	*Achenaf*

The main species grazed in the Saharan region in Bechar are fifteen (Table 3), and differ from those of the mountain region.

Table 3. Main grazed plant species in Bechar (Saharan region)

Scientific Name	Name in Arabic
Diplotaxis harra	الحارة
Euphorbia guyoniana	ام البينة
Atriplex halimus	القطف
Suaeda mollis	السويد
Stipagrostis pungens	سبط
Artemisia herba alba	الشيح
Zizyhus lotus	السدرة
Suadea fructicosa	السويد
Cotula cinerea	القرطوفة
Panicum turgidum	ام ركبة
Helianthemum lippii	رقيق
Retama retam	الرتم
Moltkiopsis ciliata	الحلمة
Erodium triangulare	الرغام
Tamarix gallica	التلايا

IV – Conclusions

Pasture is almost the goat's diet in both regions. We observed a rich biodiversity of grazed species in the Saharan range which is at the same level or even better than in the mountainous region in this study.

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Short-term evolution of edaphic parameters of mountain pastures after temporary night camping of sheep and goats

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Abstract. Pastoral mountain commons in the north of Spain are experiencing acute shrub encroachment and soil degradation. Livestock temporary night camping (TNC) is a traditional tool to concentrate fertility, generate high value grassland patches and ameliorate livestock grazing distribution. In this work we quantify the short-term effects of sheep TNC or goats TNC on soil fertility changes. Soil samples were collected 1 day before and 1 day, 2, 4 and 6 weeks after the establishment of 10 different TNC. Sheep and goat faeces were also collected after each TNC. Faeces and soil parameters measured were : pH, electrical conductivity –EC–, nitrogen, phosphorus and potassium. For faeces parameters, analyses of covariance were performed with time as covariable and livestock species as fixed effect. Each soil parameter was analyzed using mixed linear models, considering as fixed effects the livestock species, the value just before the TNC, and time. In faeces all parameters did not change with time but inter-specific differences were found, except for pH and organic matter. In all soil parameters, except EC, the value before TNC affected later values. Time was only significant for nitrogen (decrease), nitrate and EC (increase) ; no Time x Species interactions were found. Nitrogen in soil was higher for sheep TNC than for goats TNC, while the opposite trend was found for potassium, phospohrus and EC. Results are discussed with relation to the different grazing diets of sheep and goats and the characteristics of these podsolic soils.

Keywords. Cantabria – Faeces – Soil fertility – Grazing.

Evolution à court terme des paramètres édaphiques des alpages après le camping nocturne intensif d'ovins et de caprins

Résumé. *Les pâturages communs de montagne du nord de l'Espagne connaissent un empiétement important des buissons et une dégradation des sols. Le parcage temporaire de nuit pour le bétail (TNC) est un outil traditionnel pour concentrer la fertilité, générer des zones de pelouse de bonne valeur pastorale et améliorer la répartition du pâturage. Dans ce travail, nous quantifions les effets à court terme de TNC ovin ou bien caprin sur les modifications de la fertilité du sol. Des échantillons de sol ont été collectés 1 jour avant et 1 jour, 2, 4 et 6 semaines après la mise en place de 10 différents TNC. Des fèces d'ovins et de caprins ont également été collectées après chaque TNC. Les paramètres mesurée sur les fèces et le sol étaient le pH, la conductivité électrique –EC–, l'azote, le phosphore et le potassium. Pour les matières fécales, des analyses de paramètres de covariance ont été effectuées avec le temps comme covariable et les espèces d'élevage comme effet fixe. Chaque paramètre de sol a été analysé à l'aide de modèles linéaires mixtes, en considérant comme effets fixes l'espèce animale, la valeur juste avant la TNC et la date. Aucun des paramètres des fèces n'a changé avec le temps, mais des différences entre espèces ont pu être mises en évidence, sauf pour le pH et la matière organique. Dans tous les paramètres du sol, sauf pour EC, la valeur avant TNC a affecté les valeurs ultérieures. Le temps n'était significatif que pour l'azote (diminution), les nitrates et EC (augmentation) ; aucune interaction Date x Espèce a été trouvée. L'azote dans le sol était plus élevé pour les TNC ovins que pour les TNC caprins, alors que la tendance inverse a été observée pour le potassium, le phosphore et EC. Les résultats sont discutés en relation avec les différents régimes de pâturage des ovins et des caprins et les caractéristiques de ces sols podsoliques.*

Mots-clés. *Cantabria – Fèces – Fertilité du sol – Pâturage.*

I – Introduction

Livestock grazing systems in the mountain commons of northern Spain have evolved in the last 50 years towards dominance of sucker cows and mares in systems with minimum pastoral management. The acute decrease in small ruminants and the absence of herders and proper land management practices is boosting shrub encroachment by plants, especially gorses and heaths, which also reactivate uncontrolled and undesirable fires and burning regimes (Beaufoy and Ruiz-Mirazo, 2014). Shrub encroachment is linked with soil impoverishment (Montserrat, 1980), so there is an urgent need to promote practices that can revert this trend and create improved pastures to help balance livestock diets and activate sustainable grazing patterns and behaviours.

In mountain areas of Spain, the practice known as "*redileo*" (temporary night camping –TNC–) with sheep was a traditional way to fertilise cheaply and effectively meadows and pastures of commons (Fillat *et al.,* 1984). The "islands" of soil fertility created by this practice may generate grassland patches of high nutritional value (Tocco *et al.,* 2013) and of high resilience against fire.

In this study we evaluate the short-term changes of some edaphic parameters (pH, electrical conductivity –EC–, N, P and K) in patches of mixed herbaceous-shrub moorland subjected to TNC, and relate them to the quality of the faeces excreted by goats and sheep.

II – Materials and methods

1. Study area

The experiment was performed in the north of Spain (ETRS89 43º15´01´´N. 4º6´09´´W; 450 msnm), in a mountainous paddock of 4.3 ha with 17% of the area of improved pasture and the rest of moorland herbaceous-shrub vegetation. In June 2018 two small autochthonous flocks of 25 *carranzana* sheep and 25 *pirenaica* goats were introduced in the paddock and kept inside until October 2018. In the years before the experiment the area was grazed mainly by beef suckler cows at a low grazing pressure. The temporary night camps (TNC) were always set in the moorland part of the paddock, where the most abundant herbaceous species were the grasses *Agrostis curtisii*. *Pseudarrhenatherum longifolium* and *Molinia caerulea*, accompanied by short shrubs mainly of *Ulex gallii* and *Erica mackaiana*.

The soils where the TNC were installed had the following initial characteristics: pH=4.6±0.12(s.d.); electrical conductivity (EC)=0.05±0.01 mS cm^{-1}; carbonates=0.07±0.13%; organic matter (OM)=9.6±2.03%; total nitrogen (N)=0.54±0.07%; C/N ratio=10.3±1.10; P=8.5±2.94 ppm; Ca=356±84.2 ppm; Mg=77.5±28.1 ppm; K=94.0±31.1 ppm; Fe=394±53.8 ppm; Mn=1.6±1.43 ppm; exchangeable acidity=3.1±0.55 cmol kg^{-1}; Al=21±5.2 meq kg^{-1}; CEC=16.0±4.9 cmol kg^{-1}; sand=79.8±3.4%; silt=19.0±3.3% and clay=1.2±0.8%.

2. Experimental design and response variables

From July to October of 2018, 10 successive paired TNC were established. In each of these, the goats and sheep spent the night (average of 11 hours) separately in half of the TNC during 5 consecutive days, with an area of 3 m^2 per animal.

Animal faeces were collected just after the duration of each TNC, dried, sieved to 2mm and analysed for pH (water/faeces ratio 2.5 :1), EC (water/faeces 1 :5), OM (Walkley-Black method), extractable P (Olsen) and total N (Kjeldahl). From the value of N in faeces, total N added to the soil (g m^{-2}) by the animals (faeces and urine) was estimated using the equations provided by Hobbs (2006). Soil composite samples were collected from 3 fixed positions within each sheep/goat sep-

aration of each TNC just before and after the duration of the camping, as well as 2, 4 and 6 weeks after. The variables analysed in each soil sample were pH, EC, extractable P, total N, nitrates and available K. The first 5 variables were calculated as in faeces and K was extracted by emission with ammonium acetate at pH7. The nitrate content was measured by means of the Nitrachek test.

3. Statistical analyses

Temporal dynamics and livestock differences in faeces parameters were analysed using a simple analysis of covariance, with time (days) as covariable and livestock species as fixed-effect. In the case of TNC soils, mixed effect linear models were performed to analyse the temporal dynamics and possible livestock species differences of each of the measured parameters after TNC. Initial values of the soil parameters were tested as covariables, livestock species (sheep or goat) as fixed effect, days after TNC as continuous explanatory variable (in linear and quadratic terms) and specific TNC and position (goat or sheep) nested within the TNC as random effects. AIC comparisons between nested maximum likelihood models were used to attain the most parsimonious model.

III – Results and discussion

In faeces none of the variables analysed showed significant effects of time or of the interaction of livestock species with time, reflecting a fairly constant grazing diet along the studied period. pH and OM values were not significantly different for goats and sheep, while the rest of variables (EC, P, N and C/N) differed with the species (Table 1). pH was one unit higher than intensive dairy cows systems (Morgante *et al*., 2009; Luan *et al*., 2016). P and N values were highly correlated (r=0.88) and higher in sheep than in goats. The P-N correlation may be explained by the probable correlation existing for these nutrients in the plants consumed by goats and sheep. The higher values of N and P in sheep than goats were probably caused by their richer diet, as estimated for N in the simulation perfomed (0.021% vs 0.016% ; s.e.d.= 0.0009). The presumably higher dry matter intake of goats due to their higher body mass (mean values of 47 kg for ewes and 59 kg for goats), finally resulted in similar total N excretion (urine + faeces), as is suggested by the obtained simulated values (Hobbs, 2006; last row of Table 1). These simulations also predicted lower digestibility of the diet of goats (0.59) than sheep (0.66; s.e.d=0.012), which also would add for a higher faeces excretion of goats. The C/N ratio was mainly determined by the faeces N content (r=0.90). Their values for sheep were potentially more appropriate as soil organic amendment than those of goats.

Table 1. Mean values for the livestock species of the response variables characterizing the faeces collected in the temporary night camps

Variable	Goats	Sheep	s.e.d	R^2_{adj}	RSE
pH	7.72		0.057		0.26
EC (mS/cm)	0.78	1.32	0.202	0.24	0.45
OM (%)	49.80		0.985		4.41
P (ppm)	593.9	1032.1	171.3	0.23	383
N (%)	1.48	1.98	0.090	0.61	0.20
Ratio C/N	19.44	15.13	1.075	0.44	2.40
N (g/m^2)*	13.94		0.279		1.25

s.e.d.: standard error of the difference (s.e. for pH, OM and N (g/m^2). R^2_{adj}: adjusted R^2; RSE: residual standard error; * estimated according to Hobbs (2006).

In soils, most of the variables analysed showed significant changes, either with livestock species (EC, P and K), or linear increases (EC and nitrates) or decreases (N) with time after the TNC (Table 2). Only the pH remained unchanged and with values almost identical to those before TNC. For all the

response variables, except for EC, initial values immediately before the TNC were highly related to those found afterwards, denoting a low spatial variability in this type of soils of low fertility.

EC, K and P had higher values in the soils of goats TNC than in those of sheep TNC. P is mainly excreted via faeces in grazing animals, so its incorporation in the soil might be relatively slow when compared to K, which is mostly excreted in urine (Haynes and Williams, 1993). This may explain why P values in soils after TNC were not very different from values before TNC, while the contrary occurred for K and EC. The ionic form in which K is urinated explains its very high correlation with EC (r=0.91). The much higher values of K and EC in goats than in sheep do not seem to correspond uniquely to their higher intake rate, but probably also to a distinct grazing diet (Ferreira *et al.,* 2013), which may specifically be richer in K. In the case of N, the proportion excreted in urine increases with the N content of the diet. Our simulations resulted in similar proportions of N in faeces and urine. As N in urine is mainly in the form of urea, this could explain the marked increase of nitrate in the soil, possibly responding to urea hydration and posterior ammonia nitrification (Rowell, 1994). The absence of a species effect on soil N agrees with the total N excreted, as recorded in Table 1.

Table 2. Effect of livestock species and time (days) on soil variables after temporary night camps

Variable	Livestock species			Time		RSD
	Goats	Sheep	s.e.	days	s.e.	
pH	4.7		0.20	–		0.27
EC (mS/cm)	0.12	0.07	0.015	+0.0008	0.0003	0.041
P (ppm)	8.44	7.12	0.545	–		
K (ppm)	160.4	105.8	18.81	–		39.21
N (%)	0.52		0.115	-0.001	0.0004	0.05
Nitrates	0		–	+0.30	0.022	4.61

s.e.: standard error (of the difference when goats and sheep values are different). RSD: residual standard deviation of the random effects of the linear mixed model.

IV – Conclusions

Temporary night camps with high livestock density produce noticeable short-term changes in soil nutrients available to plants. Differences between goats and sheep soils may be related to their different diets. Mid and long-term changes in soil and vegetation are currently being monitored in order to quantify the utility of this practice towards pasture improvement.

Acknowledgments

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Grazing behavior and dietary preferences of sheep grazing a Mediterranean rangeland

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Abstract. Shepherds manage the feeding and grazing system of their flocks in order to achieve the coverage of animals' nutritional requirements and to maximize their productivity. The present study aimed to assess sheep grazing behavior and forage selection throughout the year, in order to provide useful information for the shepherds' management decisions. For this purpose, a flock of 250 *Chios* crossbreed sheep grazing in a hilly Mediterranean rangeland in Northern Greece was used. Grazing behavioral data was recorded using the direct observation method during three seasons (spring, summer and autumn). Measurements included the number of bites per functional plant group (grasses, forbs and woody plants) consumed by sheep. The animal's behavioral activities (feeding, walking and resting) were also recorded and analysed. Significant differences in dietary preferences were observed among the seasons. Grasses were selected mainly in spring and autumn at a rate significantly higher (60.3% and 54.2%, respectively) than summer whereas forbs were preferred in summer. Woody species were not consumed in spring whereas their contribution to sheeps'diet significantly increased in summer and autumn (21.4% and 20.5%, respectively) when the availability of herbaceous vegetation was reduced. Feeding was the main activity on the rangeland, represented an average of 70.4% of the recorded activities. Walking lasted significantly longer in autumn and resting time increased in summer probably due to the higher temperature. Despite the fact that sheep select mainly herbaceous species, woody vegetation is considered as an important forage source during the periods with low availability of herbaceous forages and it complements sheep nutrient intake.

Keywords. Selection – Grasses – Forbs – Woody plants – Behavioral activities.

Comportement pastoral et préférences alimentaires des moutons pâturant dans les pâturages méditerranéens

Résumé. *Les bergers gèrent le système d'alimentation et de pâturage de leurs troupeaux afin de couvrir les besoins nutritionnels des animaux et d'optimiser leur productivité. La présente étude visait à évaluer le comportement d'ovins au pâturage et leur sélectivité tout au long de l'année, en vue de vournir des informations utiles aux choix de conduite des bergers. À cette fin, un troupeau de 250 ovins croisés de race Chios pâturant un parcours méditerranéen vallonné du nord de la Grèce a été utilisé. Les données relatives au comportement au pâturage ont été enregistrées à l'aide de la méthode d'observation directe pendant trois saisons (printemps, été et automne). Les mesures incluaient le nombre de bouchées par groupe fonctionnel de plantes (graminées, diverses et ligneux) consommées par les ovins. Les activités comportementales de l'animal (alimentation, marche et repos) ont également été enregistrées et analysées. Des différences significatives dans les préférences alimentaires ont été observées entre saisons. Les graminées ont été sélectionnées principalement au printemps et à l'automne à un taux nettement supérieur (60,3% et 54,2%, respectivement) à celui de l'été, alors que les herbacées ont été préférées pendant l'été. Les espèces ligneuses n'étaient pas consommées au printemps alors que leur contribution à l'ingéré était nettement accrue en été et en automne (21,4% et 20,5%, respectivement), périodes où la disponibilité de la végétation herbacée était réduite. L'alimentation était la principale activité sur parcours, représentant en moyenne 70,4% du temps d'observation. La durée de la marche était supérieure en automne et le temps de repos augmentait en été, probablement en raison de la température plus élevée. Bien que les ovins sélectionnent principalement des espèces herbacées, la végétation ligneuse est considérée comme une source de fourrage importante pendant les périodes de faible disponibilité de fourrages herbacés et complète l'ingestion de nutriments.*

Mots-clés. *Sélection – Graminées – Diverses – Plantes ligneuses – Activités comportementales.*

I – Introduction

The most common sheep farming system in Greece is the traditional "semi-extensive system", where grazing is applied in communal natural rangelands and on stubble after harvest (Hadjigeorgiou *et al.*, 1999). Shepherds are managing the feeding and grazing system of their flocks in order to achieve the coverage of animals' nutritional requirements and to maximize their productivity (Manousidis *et al.,* 2016). Sheep prefer grazing than browsing and their diet consists mainly of herbaceous species (Mphinyane *et al.*, 2015). As woodlands and shrublands represent the dominant vegetation type in Greece (Papachristou *et al.,* 2005), the study of the seasonal preferences of sheep grazing in a rangeland is of great interest. The purpose of this study was to investigate the seasonal grazing behavior and forage selection of sheep in a Greek Mediterranean rangeland in order to contribute to the shepherds' management decisions.

II – Materials and methods

The research was conducted in a communal rangeland in the foothills of the *Menikio* Mountain, close to *Sfelinos* village, in *Serres* region, northern Greece, at 430 m a.s.l. The climate of the area is characterized as Sub-Mediterranean. The mean annual precipitation is 589 mm and the mean temperature is 13.2 ºC. The vegetation of the area consists mainly of herbaceous species as grasses and forbs. The area contains sparse woody vegetation usually in patches. The most common woody species are *Paliurus spina-cristi*, *Celtis australis*, *Ficus carica*, *Pyrus pyraster*, *Pyrus amygdaliformis* and *Rosa canina*. The area is grazed mainly by sheep and less by goats.

A flock of 250 *Chios* crossbreed sheep was monitored throughout the year (spring, summer and autumn), for four consecutive days during each observation period. A shepherd led the flock to a communal rangeland during all the grazing period, according to the traditionally extensive grazing system. The flock returned to the stall and was housed at night. Behavioral data was recorded using the direct observation method according to Altman (1974) sampling method and its modification described by Mancilla-Leytón *et al.* (2012) and Manousidis *et al.* (2016). Ten adult sheep were randomly selected each day from the flock in order to determine their dietary preferences. The observations were performed sequentially with an interval of 10 to 20 minutes to cover a large part of the grazing time for each day. The selected forage plants were grouped into grasses, forbs and woody species. The percentage of bites per plant group species, was used to express the forage selection by sheep, which was calculated using the following formula:

$$\frac{\text{Number of bites per plant group species}}{\text{Total bites}} \text{ X } 100$$

Sheep behavioral activities were also recorded using the regular interval observation technique with 15 min interval between observations (El Aich *et al.*, 2007). The activities were divided into feeding (grazing, browsing, walking between feeding stations), walking (directional movements), and resting (resting and/or ruminating, social activities and idling) (Schlecht *et al.*, 2006). The relative duration of each activity was calculated as the percentage of total of records per observation period.

All measurements were subjected to a one-way analysis of variance using version 8.0 of the JMP software (SAS Institute Inc, Cary, North Carolina). A multiple comparison for all pairs of means was performed using Tukey-Kramer HSD. The significance level was set to $P<0.05$.

III – Results and discussion

According to the results, significant differences in dietary preferences were observed among seasons (Fig. 1). Grasses were selected mainly in spring and autumn at a rate significantly higher (60.3% and 54.2%, respectively) than in summer, when grass availability is usually limited due to the dry and warm weather conditions (Papachristou *et al*., 2005). The contribution of forbs in sheep's diet tended to be higher in summer, but no significant differences were found between spring and summer. Woody species were not consumed in spring whereas their contribution to the diet was significantly increased in summer and autumn (21.4% and 20.5%, respectively) when the availability of herbaceous vegetation was reduced. Sheep avoid selecting woody plants in spring when the herbaceous species grow rapidly and are abundant due to the seasonal rainfalls, but when herbaceous species become scarce they rely on browsing (Rafiq *et al.*, 2010). This finding is accordance with Ngwa *et al.*, (2000), who reported that sheep spent a quarter of their grazing time browsing in a Sahelian rangeland dominated by thorn shrubs, during post-rainy and dry seasons. Additionally, Sanson *et al.* (2005) stated that sheep can be more selective compared with the larger ruminants, because of their narrow bite and split upper lip.

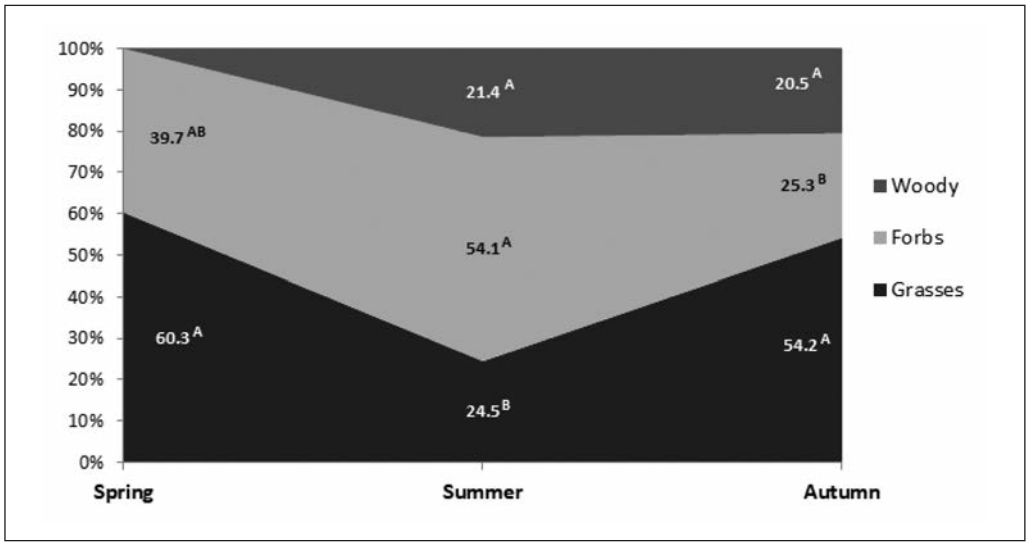

Fig. 1. Forage selection (%) by sheep in major plant categories.
Means followed by the same letter are not significantly different (P≥0.05).

Significant differences were recorded in the feeding and walking activities among seasons (Table 1). Feeding was the main activity and represented an average of 70.4% of the time. The higher percentages of feeding time were recorded in spring and summer (72.9% and 79.3%, respectively) whereas the walking activity was lowest during summer probably due to the higher temperature. Herders and animals reduced the daily walking distances during summer due to the high temperatures as they interrupted for a midday break (Akasbi *et al.,* 2012). Also, the distances travelled by Merino sheep in the Southern rangelands of Western Australia were reduced during the hot days (Thomas *et al*., 2008).

Table 1. Behavioral activities (% of daily time in the rangeland) of sheep per season

	Spring	Summer	Autumn	p-value
Feeding	72.9^{A}	79.3^{A}	59.0^{B}	***
Walking	24.6^{B}	14.8^{C}	34.5^{A}	*
Resting	2.5	5.9	6.5	NS

*P<0.05, **P<0.01, ***P<0.001, NS: non significant. Means in the same row followed by the same letter are not significantly different (P≥0.05).

IV – Conclusions

Despite the fact that sheep select mainly herbaceous species, woody vegetation is an important forage source during the dry periods with low availability of herbaceous forages in the Mediterranean rangelands, and it contributes to fulfill their nutritional requirements. However, further quantitative measurements of available forage per vegetation type could bring other useful information to optimize shepherds' grazing management practices and supplementary strategies.

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Capturing innovations in grassland-based dairy farms in Sardinia (Italy)

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Abstract. Inno4Grass is the acronym for "Shared Innovation Space for Sustainable Productivity of Grasslands in Europe", an international and multi-actor project gathering prominent farmers' organizations, extension services, education and research institutions from eight EU countries. The overall objective of the project is to bridge the gap between practice and science communities to ensure the implementation of grassland innovations at farm level. After a brief introduction about the overall structure of Inno4Grass, we will focus on the outcome of a farm survey carried out in Sardinia (Italy). Ten innovative dairy farmers were interviewed. Information was collected using a standardised questionnaire based both on farm structure parameters and on open questions concerning the general farm functioning and the specific innovations adopted by farmers. The farm innovations covered different domains: production techniques (i.e. new grassland mixtures), products (i.e. cheese processing) and farm organization (i.e. labels and marketing). Several innovations were often identified within the same farm. Most farmers' strategies were oriented towards the reduction of production costs. Their decisions could be a good example for other potential innovators.

Keywords. Dairy farms – Grassland – Innovation – Survey.

Capturer les innovations dans les fermes laitières herbagères en Sardaigne (Italie)

Résumé. *Inno4Grass est l'acronyme pour « Un espace partagé autour de l'innovation pour des prairies productives et durables en Europe», un projet international et multi-partenarial regroupant d'importantes organisations professionnelles d'agriculteurs, des établissements d'enseignement agricole et des instituts de recherche de huit pays européens. L'objectif général du projet est de combler le fossé qui sépare les communautés de praticiens et scientifiques afin de garantir la mise en œuvre d'innovations dans les prairies, à l'échelle des exploitations. Après une brève introduction sur la structure générale d'Inno4Grass, nous nous concentrerons sur les résultats d'une enquête agricole réalisée en Sardaigne (Italie). Dix éleveurs innovants ont été interrogés. Les informations ont été collectées à l'aide d'un questionnaire normalisé basé à la fois sur les paramètres de structure de l'exploitation et sur des questions ouvertes concernant le fonctionnement général de l'exploitation et les innovations spécifiques adoptées par les agriculteurs. Les innovations agricoles couvraient différents domaines : techniques de production (nouveaux mélanges prairiaux), produits (transformation fromagère) et organisation agricole (étiquettes et commercialisation). Souvent, plusieurs innovations étaient identifiées au sein d'une même ferme. La plupart des stratégies des agriculteurs étaient orientées vers la réduction des coûts de production. Leurs décisions pourraient être un bon exemple pour d'autres innovateurs potentiels.*

Mots-clés. *Fermes laitières – Prairie – Innovation – Enquête.*

I – Introduction

The international and multi-actor project "Shared Innovation Space for Sustainable Productivity of Grasslands in Europe" (Inno4Grass) gathers prominent farmers' organizations, extension services, education and research institutions from eight EU countries. It aims at filling the gap between practice and science, focusing on grassland-based farming systems, on their status concerning innovations and on the needs for their sustainable improvement in the future. Several regimes of innovation co-exist (Joly *et al*., 2013). The two main regimes regarding grasslands are the centralised

innovation regime and the innovation through participatory experiments. Inno4Grass approach is based upon a combination of both. Because of the high dependency on local conditions, many innovations arise from farmers as they exploit the diversity of conditions. The centralised approach makes it possible to consolidate such innovations through science and generic knowledge. Moreover, this dual approach improves the novelty and its adoption, both aspects being at the very core of innovation (OECD, 2005). A total of 170 innovative farmers were identified and interviews were carried out in the eight EU countries for different farm types (dairy, beef, sheep). These breeders were considered as lighthouse-farmers from which the less innovative farmers in Europe could learn for the adoption of farm innovations. In this paper we focus on the results collected in Sardinia.

II – Materials and methods

1. Farmers selection and interviews

Interviews were conducted in Sardinia (Italy), from September 2017 to April 2018. Ten innovative farmers were identified, either with the help of the stakeholders who had signed an endorsement letter for this purpose with the project consortium, or selected among the farmers' network of CNR-ISPAAM. Nine farms bred dairy sheep and one farm bred dairy cows.

Face-to-face interviews were carried out by setting up a specific questionnaire composed by two main sections (OECD, 2005). The first section focused on social data, environmental characteristics, farm structure, availability of grasslands and their management, livestock consistencies and animal performances. The second section focused on the farm's innovations, either directly or indirectly linked to grasslands, on the farmers' strategy that pushed the adoption of the innovation, on the benefits obtained by the farmer and on the eventual unsatisfied needs.

III – Results and discussion

The farms displayed a different organisation, depending on the site, on its characteristics and on farmers' choices. The farmers were on average 50 years old. The average surface area of the farm was 126.6 ha, ranging from 78 to 180 ha. Most of the farmland was owned by farmers.

Eight farms included temporary grasslands that covered 11 to 92% of the total farm area. Four farms were based on permanent pastures. In three cases (farms 1, 5 and 10), permanent pastures were recovered after the abandonment of annual crops (cereals). Such semi-natural pastures contained mainly annual legumes (clovers and medics), annual grasses and, sometimes, shrubs of the Mediterranean maquis. In farm 7, permanent grasslands were recovered after the abandonment of annual crops as well, but improved pastures based on legume-grasses mixtures were sown.

The prevailing use of grasslands was grazing, except for farm 6 where dairy cows were stabled. Nonetheless, most grasslands were mown after the grazing season. Only in farms 3, 6 and 9, a variable portion of the grassland surface area was exclusively mown to produce hay.

Grassland-related innovations covered several domains: (i) use of innovative machinery (D1), sometimes self-built; (ii) forage mixtures or species (D2); (iii) management of the grazing system (D3); (iv) legume management (D4); (v) animal breed (D5); (vi) production of new dairy products (D6); marketing strategies (D7).

Most farmers adopted several innovations, usually a combination of two or three, which indicated a holistic approach to innovation which, in some cases, required a total change of farming system (Farms 2, 6 and 7).

Table 1. Farm structure of the innovative farms

Farm	TA (ha)	FA (ha)	PGs (ha)	TGs (ha)	eGrA (% FA)	eMoA (% FA)	MU (% FA)	NA (LSU)
Farm 1	180	180	120		66		33	45
Farm 2	150	150		55	63.3		36.7	25
Farm 3	82	77		77	54.9	19.5		55.2
Farm 4	180	160		160	10.1		89.9	79
Farm 5	90	70	60	10	85.7		14.3	26
Farm 6	200	185		185		100		498
Farm 7	79	76	59	17			100	54.3
Farm 8	78	70,5		65.5	10		90	72.5
Farm 9	180	174		161		3.3	96.7	122.1
Farm 10	120	70	34		100			40

TA=total farm area; FA=main forage area; PGs= permanent grasslands; TGs=temporary grasslands; eGrA=exclusively grazed area; eMoA=exclusively mown area; MU=mixed-used area; NA=number of animals in Livestock Unit.

Table 2. Domain of innovations (D) in the ten Sardinian farms

Farm	Domain of innovation (D)	Short description of the innovations
Farm 1	D6, D7	Several types of cheese are produced using the thistle rennet. Sales of cheese with the trade mark «qualità vegetariana». Online sales.
Farm 2	D5, D7	Breeding of a native sheep breed; farm shop; online sales.
Farm 3	D1, D4, D5	Use of a modified precision seeder. Innovative legume-cereal mixtures (pink serradella and wheat or barley). Breeding of two dairy sheep breed.
Farm 4	D5, D6, D7, D8	Breeding of three species of dairy animals (sheep, goat, cow). Production of unique cheese types (semi-seasoned cheese and unusual cheese seasoning). Farm holiday. Farm shop.
Farm 5	D7, D8, D9	Farm shop, online sales. Cheese brand (Latte nobile). Production of environmental services.
Farm 6	D1, D2, D5, D9	Sod-seeding of forage plants. Use of legume-based mixtures. Animal type (cross-breeding). Production of environmental services.
Farm 7	D2, D3, D7	Local self-reseeding legume-based mixtures (burr medic, subterranean clovers) and perennial species. Short rotational grazing. Out-of season lambing. Farm shop. Shop in the nearby town. Online marketing.
Farm 8	D2, D3, D8	Forage self-sufficiency. Forage system based on temporary grasslands as subclovers and medics in mixture with cereals. Annual cereal-legume forage mixtures (Trifolium alexandrinum or T. incarnatum or T. resupinatum). Sulla.
Farm 9	D4, D6, D7, D9	Sod seeding (Italian ryegrass on lucerne). Production of innovative cheese (also with herbs). On farm sales, farm-to-fork sale circuit with a shop in the city centre. Almost energy self-sufficient (photovoltaic panels).
Farm 10	D3, D6	100% semi-natural pasture-based milk. Agroforestry. Cross-bred sheep. New cheese processing techniques. Production of a range of dairy products.

D1=machinery, tools; D2=forage mixture; D3=grazing management system; D4=legume management; D5=animal breed or type; D6=product or product processing; D7=marketing; D8=farming system; D9=other.

The reasons that pushed farmers to adopt innovations were mainly the need to solve specific problems and to decrease production costs. Among the specific problems, improving the independence of their incomes from milk market price volatility seemed to have a great importance among farmers. Stabilising their income was one of the main drivers that pushed the adoption of innovations.

Table 3. Farmers' strategy (S): the drivers that push farmers to adopt innovations

Farm	Farmers' strategy	Short description of farmers's strategy
Farm 1	S1, S4, S5	Find new niche markets for cheese (vegan/ vegetarian consumers). Set up new cheese processing techniques. Sell products.
Farm 2	S1, S3, S7	Produce very high-quality cheese to be sold in niche markets. Decrease milk production costs.
Farm 3	S1, S2, S3	Improve forage quality and availability. Improve sheep milk production. Decrease milk production cost.
Farm 4	S1,S4,S7	Increase the potential number of consumers (market). Increase the range of dairy products.
Farm 5	S1,S3,S5,S7	Overcome the market saturation of cheese produced from pasteurized milk. Production of healthier cheese.
Farm 6	S1,S2, S3	Save labour. Reduce costs of soil tillage. Increase environmental services.
Farm 7	S3,S7	Reduction of labour intensity for grassland management. Reduce the influence of milk price volatility on farmer income.
Farm 8	S1,S2,S3	Improving animal health (condensed tannins). Decreasing costs for extra-farm inputs.
Farm 9	S3,S4,S5	Stabilising income among years to plan investments. Reduce costs for soil tillage.
Farm 10	S2,S3, S5	Improve cheese yield from sheep milk. Improving dairy products quality and health. Improve income.

S1=solving a specific problem; S2=obtaining a higher production; S3=decreasing costs; S4=processing products; S5=short market chain; S6=curiosity in the subject or technique; S7=other.

IV – Conclusions

The farmers interviewed provided examples of how farms and farmers' income can be improved using several strategies and specific innovations. The solutions that they found to solve specific problems and their implementation can serve as a guide for other farmers at local, national and trans-national scales. These farmers can be considered as a source of inspiration for other farmers who need to improve their conditions under Mediterranean climate.

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Production and grazing utilization of *Medicago arborea* by Sarda ewes and their performance in an extensive grazing system

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Abstract. A crop of 1000 seedlings (25-30 cm in height) of the shrub *Medicago arborea* was established in spring 2017 in the experimental farm of Bonassai (N-W Sardinia, Italy) to study its forage production and nutritive value in Sarda sheep grazing system. Plants were transplanted at 1 m from each other in rows 4 m apart (2500 plant ha^{-1}). In 2018, plant height and diameter were measured, monthly. In July 2018 and in January 2019 (grazing periods) a plot (3500 m^2) of *M. arborea* was grazed by 24 mature Sarda dairy ewes for 14 days. Before the beginning and after the end of each grazing period, the available edible biomass (dry matter) and its nutritive value were evaluated. All ewes were supplemented with concentrate and hay. Animal performance was assessed three times during each grazing period, at the beginning (Beg), the middle (Mid) and the end (End). Available edible biomass was 604 ±40 and 526 ±26 kg ha^{-1} in July and January, respectively. Crude protein content was always greater than 150 g kg^{-1} DM. In both grazing periods, the ewes ingested more than 80% of the available crop edible biomass. The body weight and body condition score of ewes did not change between Beg and End of grazing. Daily milk production decreased at the end of the grazing period due to a reduced dry matter availability. Milk fat, protein, and casein did not significantly change between Beg and End of grazing. To conclude, *M.arborea* could contribute to cover dairy sheep requirements during periods of herbage shortage.

Keywords. *Medicago arborea* – Dairy ewes – Grazing system – Edible biomass.

Production de* Medicago arborea *et utilisation par des brebis Sarde au pâturage

***Résumé**. Une plantation de 1000 plants (de 25 à 30 cm de hauteur) de l'arbuste* Medicago arborea *a été établie au printemps 2017 dans la ferme expérimentale de Bonassai (nord-ouest de la Sardaigne, Italie) pour étudier sa production fourragère et sa valeur nutritive dans le système de pâturage extensif de la brebis de race Sarde. Les plants ont été transplantés à 1 m les uns des autres, en rangs espacés de 4 m (2500 plantes ha^{-1}). En 2018, la hauteur et le diamètre des plants ont été mesurés tous les mois. En juillet 2018 et en janvier 2019 (saisons de pâturage), une parcelle (3500 m^2) de M. arborea a été pâturée pendant quatorze jours par vingt-quatre brebis laitières Sardes. Avant le début et après la fin de chaque saison de pâturage, la biomasse consommable (matière sèche) et sa valeur nutritive ont été évaluées. Toutes les brebis ont été supplémentées avec du concentré et du foin. Les performances des animaux et le comportement alimentaire au pâturage ont été évalués à trois reprises au cours de chaque saison de pâturage : au début, au milieu et à la fin. En juillet et en janvier, la biomasse consommable était de 604 ± 40 et 526 ± 26 kg ha^{-1} de MS, respectivement. La teneur en protéines était toujours supérieure à 150 g kg^{-1} de MS. Les brebis ont ingéré plus de 80% de la biomasse consommable. On n'a pas enregistré de variation de poids vif ou de note d'état corporel des brebis au cours de la période de pâturage. La production du lait journalière a été réduite à la fin de la période de pâturage en raison d'une moindre quantité de matière sèche disponible. Les taux protéique et butyreux ainsi que la caséine du lait n'ont pas changé de manière significative pendant la période de pâturage. Cette étude suggère que M. arborea peut contribuer à couvrir les besoins énergétiques des animaux en période de carence en herbe.*

***Mots-clés.** Medicago arborea – Ovins laitiers – Système de pâturage – Biomasse consommable.*

I – Introduction

Climate change indicators (i.e. droughts, floods, soil erosion) suggest the adoption of farming systems adapted to the expected climatic conditions (Altieri and Nicholls, 2013). Soil conservation practices, use of perennial native plant species and low inputs crops are indicated as putative strategies to face variable environmental conditions (Wall and Smit, 2005). In this context, woody species such as drought resistant forage shrubs could have an important role in Mediterranean livestock systems (Papanastasis *et al*., 2008). Tree medic (*Medicago arborea* L.) is a leguminous shrub native to the Mediterranean region, drought and cold resistant. Its growing season last from autumn until late spring with a growth stasis in summer, depending on rainfall distribution (Amato *et al.,* 2004, Papanastasis *et al.,* 2008, de Koning *et al.,* 2000). *M. arborea* has high nutritive value and palatability and can complement biomass production of natural pasture which is usually low from late spring up to early autumn and in winter. Dry matter (DM), production ranges from 1 to 3 t y^{-1} depending on environmental conditions (Amato *et al.,* 2004). Moreover *M. arborea* has shown to reduce soil erosion in endangered marginal areas (Andreu *et al.,* 1998). If properly managed, *M. arborea* could become an interesting forage resource for farms, by saving annual soil tillage and avoiding the cultivation of forage crops. Its lifespan, which depends on adaptation to environmental conditions and genetic resistance to plant disease, could be at least 10 years. This study aims to evaluate *M. arborea* crop forage production and its nutritive value under Sardinia climatic conditions, with a management consisting in an intensive grazing by sheep twice a year, in winter and early summer. Grazing periods and management were chosen with the aim to tackle the shortage of herbaceous pasture that occurs in Mediterranean environment, meanwhile keeping shrub plant growth under control by grazing (Stringi *et al.,* 1997, Amato *et al.,* 2004). Moreover, the study aims to assess animal performance response during the two grazing periods.

II – Materials and methods

The experiment was carried out at the *Bonassai* research station (NW Sardinia, Italy, 40°39'46''N, 8°21'46''E, 33 m.a.s.l) from spring 2017 to early winter 2019 on a clay loam alkaline soil (pH 8.2) with a high content of active lime (109.6 g kg^{-1}) and exchangeable K (335 mg kg^{-1}), an average content of total N (1.69 g kg^{-1}) and a low assimilable P (10.4 mg kg^{-1}). The average long term annual rainfall, minimum and maximum temperature are 583 mm, 9.8°C and 21.7°C, respectively (source ARPAS http://www.sar.sardegna.it/).

In spring 2017 a crop of 1000 seedlings (25-30 cm in height) of *M. arborea* was established in a tilled and fertilized field (92 kg ha^{-1} P_2O_5). Plants were hand-transplanted at 1 m from each other in rows 4 m apart (2500 plant ha^{-1}). A mulching film was placed on the plant rows to prevent weed growth. From January to December 2018, plant height and diameters (in row direction and perpendicularly) were measured, monthly.

In July 2018 and in January 2019 (grazing periods) a plot (3500 m^2) of *M. arborea* was grazed by twenty-four mature *Sarda* dairy ewes (stocking rate 10 LU ha^{-1}) for 14 days and 6 hours per day. Grazing periods started when the edible biomass available was deemed adequate to feed the sheep for an estimated grazing time of at least 14 days. This period of time has been considered a prerequisite to assess animal response. Sheep were selected for similar body weight (BW), body condition score (BCS) and, if milked, milk production. The experimental animals were 4-5 years old lactating (milked) ewes in January and dry ewes in July. All ewes were supplemented according to the typical feeding management of *Sarda* ewes: in July with 500 g $head^{-1}day^{-1}$ of Italian ryegrass hay and 100 g $head^{-1}day^{-1}$ of concentrate, and in January with 700 g $head^{-1}day^{-1}$ of alfalfa hay and 500 g $head^{-1}day^{-1}$ of concentrate.

Before grazing, herbage biomass between rows was removed by cutting at low height to minimize herbaceous pasture availability. At the beginning (Beg), in the middle (Mid) and at the end (End)

of each grazing period (grazing time) animal response in terms of milk yield and composition, body weight (BW) and body condition score (BCS) were assessed. Before and after each grazing period, in 15 plants randomly chosen inside the experimental area, the available edible biomass (DM kg ha^{-1}) was evaluated by hand plucking of all leaves, flowers, pods and twigs (<3mm of diameter). Samples were oven-dried at 65°C to determinate the content of crude protein (CP), neutral detergent fibre (NDF), and *in vitro* DM digestibility (IVDMD) by near-infrared reflectance spectrometry (NIRS). Animal data were analysed using a GLM model of SAS (SAS Institute, 2002), with grazing time within each grazing period as fixed effect, and Tukey-Kramer *t*-test to separate means.

III – Results and discussion

2017 and 2018 were both characterized by maximum annual temperatures higher than long term values (22.6°C and 22.1°C, respectively) associated with low rainfall in 2017 (368.4 mm) and high rainfall in 2018 (833.8 mm). In 2018 plant height ranged between 36.5±0.4 and 80.4±0.6 cm, and plant diameter between 27.9±0.6 and 71.1±0.8 cm. In July 2018, after grazing, plant height and diameter decreased by 9.2 and 19.5 cm, respectively. Edible biomass available was 604 ±40 kg ha^{-1} and 526 ±26 kg ha^{-1} in July 2018 and January 2019, respectively (Table 1). In January, the forage nutritive value was slightly higher than in July, with higher CP and IVDMD contents and lower NDF and ADF contents. Sheep ingested over 80% of the available edible biomass in July (494 ±35 g $head^{-1}$.day) and over 90% in January (528 ±26 g $head^{-1}$.day). Thus, after grazing the standing biomass was 103 ±8 and 29 ±2 kg ha^{-1} in July and January, respectively. These results are comparable with that found by Stringi *et al.* (1997) in Sicily where a tree medic crop was grazed by a similar stocking rate of *Comisana* sheep in January and June.

Table 1. Tree medic edible biomass, at the beginning of grazing in July and January (mean ±SE)

Season	Edible DM (kg ha^{-1})	CP (g kg^{-1})	NDF (g kg^{-1})	ADF (g kg^{-1})	IVDMD (g kg^{-1})
July 2018	604 ± 40	161 ± 2	418 ± 3	312 ± 3	669 ± 3
January 2019	526 ± 26	199 ± 3	348 ± 4	252 ± 3	728 ± 4

Table 2. Body weight (BW, kg) and body conditions score (BCS) of ewes in July 2018 and January 2019 (mean ±SE)

Grazing Time	July 2018		January 2019	
	BW	BCS	BW	BCS
Beg	47.02 ± 1.14	2.64 ± 0.06	43.62 ± 2.49	2.49 ± 0.05
Mid	44.55 ± 1.21	2.58 ± 0.05	43.43 ± 0.70	2.54 ± 0.04
End	46.85 ± 1.36	2.62 ± 0.05	44.10 ± 0.70	2.44 ± 0.05

Body weight and BCS did not change between Beg and End of grazing in July and January (Table 2). This result shows the ability of M. arborea to keep sheep in similar body conditions than when they are managed in the traditional forage system. In January, daily milk yield decreased from Mid to End of the grazing period (2130 ±75.81 and 1850 ± 73.38 g $head^{-1}d^{-1}$, respectively, $P<0.05$), likely due to a reduced availability of edible biomass at the end of the grazing period (Fig. 1). Salis *et al*. (2018) observed an increased milk yield in *Sarda* ewes grazing *Tagasaste* forage shrub, with edible biomass higher than 500 kg ha^{-1}. In this context when shrub edible biomass is strongly reduced, animals could be moved to others pasture, or should be fed supplements. Milk fat, protein and casein did not significantly change from Beg to End whereas some differences were detected in the first part of grazing period (from Beg to Mid). Milk protein significantly increased (4.79 ± 0.07 *vs*

5.03 ± 0.07 %, P<0.05) whereas casein decreased (3.66 ±0.06 vs 2.89 ±0.05 %, P<0.01). Moreover, milk urea increased in Mid (58.14 mg/100mL^{-1}) and End (52.05 mg/100mL^{-1}) of grazing as compared to Beg (38.85 mg/100mL^{-1}, P<0.01).

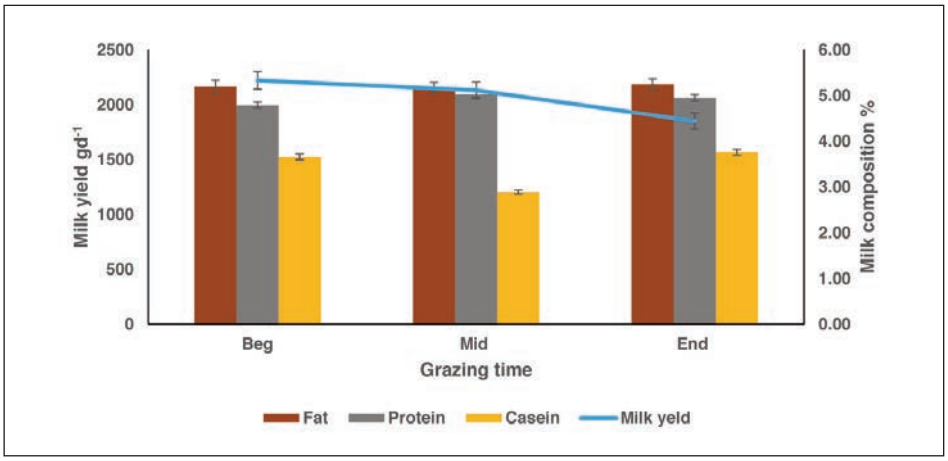

Fig. 1. Sheep milk yield (g head^{-1}d^{-1}) and its chemical composition (%, g 100mL^{-1}) in January.

IV – Conclusions

Medicago arborea proved tolerant to alkaline soil with high content of active lime. The plants grazed twice a year were able to tolerate (in the 2 experimental years) a high stocking rate that limited plant size. They showed a good re-growth after grazing and offered more than 1000 kg DM ha^{-1} of edible biomass per year, covering the energetic requirement of animals during periods characterized by herbage shortage. The high protein content (always > 150 g kg DM^{-1}) and IVDMD of *Medicago arborea* highlight the quality of this forage that allowed high milk yield and milk quality, without relevant changes of BW and BCS. *Medicago arborea* crop could be integrated among the forage resources in rainfed Mediterranean sheep systems, despite its low growth and low weed competition in the first year after establishment. Further research is needed to check if intercropping forage species between shrub rows could improve productivity and economical sustainability of *M. arborea* crop-system.

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Characterizing pastoral land on a large scale : a way to assess better the resilience of Mediterranean livestock activities.
Lessons learned from a study on the scale of the Provence Alpes Côte d'Azur region (France)

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Abstract Given the mobility of people and animals, the diversity of land tenure systems and of the associated environments, the identification of grazing land over large areas is an uncertain exercise, especially when it comes to defining the expanse of land concerned and its type. Improving the characterization of grazing lands is needed to analyse the resilience of pasture-based systems in a context of global changes. Our study started with the determination of the diversity and spatial distribution of vegetation types within the grazing land of a small region, based on testimonies from livestock farmers. On this basis, we characterized land use by remote sensing at the scale of a small test region (611 km^2). The characterization of land use in these areas is a major challenge that cannot be met merely by analysing declarative data or by using a conventional map where land categories cannot be connected to grazing management practices. On the basis the land use map we produced, we identified that animals' access to the pastoral resource is problematic in a large proportion of the grazing area (35%) due to shrub encroachment and forest expansion. This puts forward a weakness of pastoral farming in terms of future dynamics.

Keywords. Pastureland – Characterization – Remote sensing – Spatial distribution.

Caractériser l'espace pâturé à large échelle : un moyen de mieux évaluer la résilience des activités d'élevage en Méditerranéen. Enseignement d'une étude à l'échelle de la région Provence Alpes Côte d'Azur (France)

Résumé. *Du fait de la mobilité des hommes et des animaux, de la diversité des statuts fonciers et des milieux concernés, l'identification de l'espace pastoral pour des ensembles spatiaux étendus est soumise à de fortes incertitudes tant sur l'étendue des surfaces concernées que sur leur nature. Mieux caractériser ces espaces est important pour analyser la résilience des systèmes confrontées aux changements globaux. Notre étude a d'abord caractérisé la distribution spatiale et la diversité des formations végétales de l'espace pastoral d'une petite région à partir de déclarations d'éleveurs. Sur cette base, nous avons caractérisé l'occupation du sol par télédétection à l'échelle d'une petite région test (611 km^2). La caractérisation de l'occupation du sol de ces espaces est un enjeu fort qui n'est résolu ni par l'analyse des données déclaratives ni par l'usage d'une carte généraliste dont les catégorisations ne permettent d'établir un lien avec les pratiques pastorales. Sur la base de la cartographie d'occupation du sol que nous avons réalisé, l'accessibilité pour les animaux à une ressource pâturable est en question pour une forte proportion de l'espace pastoral (35%) du fait de la forte dynamique de fermeture des milieux Ceci souligne des fragilités de l'activité en termes de dynamiques futures.*

Mots-clés. *Espace pastoral – Caractérisation – Télédétection – Distribution spatiale*.

I – Introduction

In Provence-Alpes-Côte D'Azur, livestock farming occupies significant proportions of the regional territory. It plays a structural role in land use and in the socio-economic environment of rural areas. Its highly pastoral nature makes it an important contributor to the development of natural areas, particularly ecologically sensitive sites and those characterized by the multiple use of land.

Grazing is often the only human activity in these areas. Unlike other agricultural practices (such as ploughing or mowing), it is difficult to establish spatial records of this practice because the animals move around. Within a particular farming territory, how frequently or how intensively pastureland is used depends on whether the land in question lies within the farm's main grazing area or is a back-up area used when adverse climate events lead to a shortfall in fodder production.

It is important to characterize the spatial distribution of livestock activities to better analyse interactions with plant dynamics in grazed areas. The management of these interactions governs the long-term renewal of the pastoral resource. Generally, over the medium term, the region's grazing areas undergo encroachment dynamics, with the growth of tree and forest layers that jeopardize the availability and accessibility of the forage resource. These ecological dynamics are heightened by a downward trend in grazing pressure and minimal human intervention to control woody plants. The increasing frequency of adverse climatic events might strengthen the need for additional grazing areas to secure systems' resilience. In the meantime, the management practices in pastoral land areas are reducing their ability to supply fodder over the medium term. These processes have been clearly identified in small samples of farms monitored by extension services and research. However, there is little documentation of the trends at the regional level, even though use of these areas is affected by the global changes operating at these larger scales.

Our work aimed to better characterize the pasturelands of the PACA region in terms of spatial distribution and diversity of vegetation types concerned. Based on such results, we assessed the overall sustainability of the pastoral system, and especially its ability to renew the resources on which it depends. We also examined its ability to take into account the expectations of the other stakeholders involved.

II – Materials and method

1. Area of study

The Provence-Alpes-Côte D'azur (PACA)[1] region covers an area of 31,400 km^2 in south-eastern France. The marked altitudinal gradient and the strong contrasts in vegetation types shape the region into a number of large spatial entities (the Mediterranean coast, the Alpine zone and the *Rhone* and *Durance* valleys). Livestock systems based on the high seasonal mobility of herds (transhumance) have emerged, adapted to this geographic diversity. The region is split into six administrative departments. This roughly corresponds to the area within which the herds move, which is the entity analysed in this study.

We used two data sources: the *Registre Parcellaire Graphique* (RPG or graphic land registry) (Cantelaube and Carles 2014) and the *Enquête Pastorale* (EP or pastoral survey) (Enquête pastorale 2014). We analysed the spatial distribution of grazed areas, as recorded in these two sources. It is worth noting that the regional extent and location of grazed land differed depending on the meth-

1. The PACA region, https://www.maregionsud.fr/la-region/un-territoire.html

ods of assessment: the RPG estimated the grazed surface area at 553,205 hectares in 2014 and the EP at 877,981 hectares. We focused our analysis on the areas common to these two sources, considering that they are the core of the areas grazed by livestock in the region.

We carried out our study on the scale of an area that is deemed homogeneous in terms of its geomorphology and the nature of its agricultural activities: the Haut Verdon Annot-Saint André *géoterroir* located in the Alpes de Haute Provence *département* (04), which covers an area of 611.28 km^2. It is a diversified entity, which includes pre-alpine and mountain environments, with large areas used by livestock.

2. Vector data

The data analysed refered to the year 2014, in order to: (i) establish a baseline year before implementation of the 2015 CAP, and (ii) compare data from RPG and data from the last pastoral survey which took place in 2012-14.

France has established a register of agricultural plots since 2002, known as the 'graphic land registery' or *Registre Parcellaire Graphique* (RPG), based on farmers' CAP declarations and administered by the *Agence de Services et de Paiement* (ASP). The RPG is a source of annual georeferenced land-use information made available by INRA's Rural Development Observatory (ODR) department[2].

Three pastoral surveys have been carried out on the scale of the Alpine massif since the 1960s. The last one was conducted in 2012-14. The survey lists grazing areas of more than 10 hectares. The EP results in a georeferenced database that can be used in all GIS software. The data were provided for this study by the *Centre d'Etudes et de Réalisations Pastorales Alpes Méditerranée* (CERPAM).

3. Raster data

The SPOT 6 images for the year 2014 were provided by EQUIPEX GEOSUD[3]. The SPOT 6/7[4] satellites provide the 60-km imaging swath in two modes simultaneously: (i) panchromatic with 1.5 m resolution: this product includes a single band in the wavelength range of 0.45µm to 0.745µm; (ii) multispectral with 6 m resolution, comprising four spectral bands: B1 (Red 0.530µm-0.590µm), B2 (Green 0.760µm-0.695µm), B3 (Blue 0.455µm-0.525µm), and B4 (PIR 0.760µm-0.890µm).

The image processing chains of this study were based on open source software, notably the Orfeo Tool Box[5], a satellite image-processing library designed for high spatial resolution images, developed by CNES. OTB algorithms can be run from QGIS, which is also free GIS software.

4. Method

Our objective was to (i) identify large-scale grazed areas from the two sources of declarative data and make cross-checks to weight uncertainties relating each source and the contrasts between sources, and (ii) characterize land use by distinguishing five land use classes for grazing land: forests, closed moorland, open moorland, meadows, and bare ground.

2. The ODR is a software platform created and managed by INRA, the French National Institute for Agricultural Research.
3. The EQUIPEX GEOSUD project
4. SPOT 6 | SPOT 7– https://www.intelligence-airbusds.com/files/pmedia/public/r12784_9_spot6-7_fiche_technique.pdf
5. Orfeo Toolbox – https://www.orfeo-toolbox.org/

Grazing areas are made up of spatial entities where the interactions between the natural dynamics of vegetation types and human activities (mainly bringing herds to pasturelands) determine land use. Our five land use classes reflect both past use patterns and the potential for future use of these areas for grazing: open moorland and meadows are the preferred areas for grazing, while closed moorland and forests remain are less interesting due to limited accessibility of the pastoral resource. Figure 1 illustrates the spatial arrangement of these areas and their role in feeding herds.

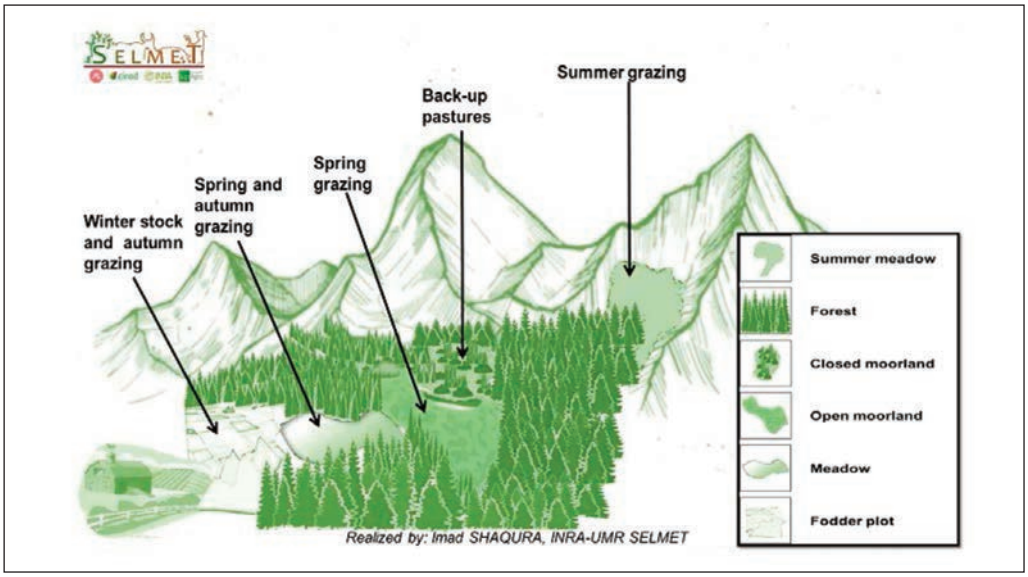

Fig. 1. Diagram showing the spatial arrangement of grazing areas and their role in livestock feeding systems.

III – Results

The confusion matrix report produced by QGIS for the supervised classification algorithm (Bayes), implemented in Orfeo Toolbox (OTB), validates the results from the SPOT 6 image classification process. We have overall accuracy of 86.8 and a Kappa index of 84.2%.

Table 1 and Figure 2 show the distribution of grazing areas in the five land use classes according to the data sources used to identify these areas (RPG, pastoral survey or both). At the scale of the *Haut Verdon-Annot-Saint André* geoterroir, the distributions of the different land use classes, according to the data source, converge. For the analysis, we will thus focus our attention on the areas declared in both databases.

Closed moorlands are the land use category most frequently identified (32%). This means that over one third of the grazing areas in this géoterroir are in areas where there is no guaranteed access to the resource in the medium term. In fact, according to our hypothesis, these are areas are mainly grazed as 'back-up' in years when adverse climate events have limited production and thus might not endure a sufficient grazing pressure to limit shrub encroachment. In these pastoral systems, resilience to climatic events is thus dependent on areas where the practices applied may not be capable of maintaining this function over the medium term due to low stocking rates and weak control of vegetation dynamics by grazing practices.

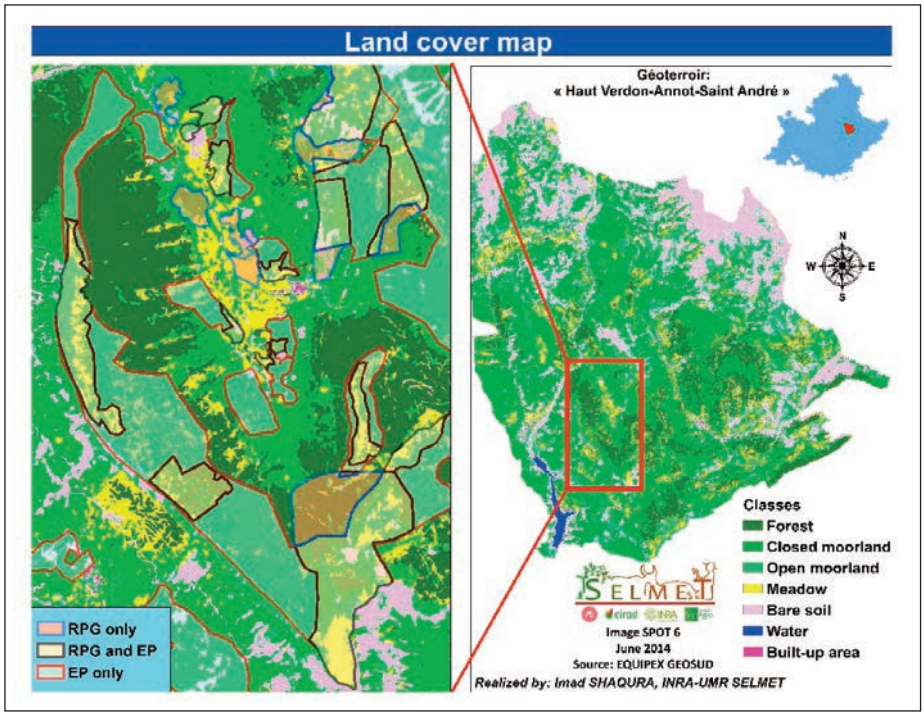

Fig. 2. Land use map (Haut Verdon-Annot-St André).

Table 1. Percentage of each land use class by data source (*Haut Verdon-Annot-St André*)

Land use class	Both the RPG and the Pastoral Survey		Pastoral Survey only		RPG only	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest	265.3	2.0	1149.2	5.0	418.71	2.8
Closed moorland	4225.7	32.0	8290.8	35.8	5141.47	33.8
Open moorland	3141.6	23.8	4541.8	19.6	3439.52	22.6
Meadow	1211.5	9.2	2057.1	8.9	1404.87	9.2
Bare soil	4341.8	32.9	7128.2	30.8	4799.73	31.6
Total	13186.1	100	23167.1	100	15204.3	100

It is worth noting the low values for grazed forest. In contrast to other land use classes, the bare soil category is highly represented (approx. 33%). These high values can be explained by the prominence of high mountain summer pastures in this géoterroir. These two land use classes comprise areas whose eligibility for CAP support is debated. The open moorland and meadow classes – ideal grazing areas – together account for only one third of the grazed areas, which can seem little, even if the contributions of these surfaces is much higher when expressed in terms of amounts of forage ingested.

IV – Conclusion

This study emphasizes how valuable large-scale georeferenced databases are when characterizing interactions between grazing practices and trends in the use of grazed land. If land cover may be easily determined thanks to new developments in remote sensing, land use practices are still

poorly documented at these scales, although, participative mapping and easy access to public information should improve the situation in a near future. In our situation, comparing data from different sources remains necessary to compensate the uncertainty associated with each evaluation system. Availability of data about grazing land is the main limit to the reproductibility of this research.

Scrub encroachment and forest growth are responsible for the closing-off of natural grazed areas in medium mountains. This is a particularly strong tendency in the French Mediterranean region. The extension of these closed areas will likely jeopardize the high resilience of livestock systems to adverse climatic events, which have become more frequent in recent years. Although it would be very costly, these areas should therefore be mechanically cleared, to strengthen the sustainability of the systems. Considering the low short-temr economic return of such investment, it could only be implemented with public supports, as a means to facilitatethe multiple use for these areas (recreational, forestry, fire protection...). Alternatives solutions for livestock systems include reallocation of grazing to other areas through a greater mobility of herds, and/or increasing feed supplementation as an alternative to grazed forage.

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Milk production of dairy ewes fed in stall or grazing green barley or ryegrass pastures

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Abstract. Sheep dairy production depends on many factors such as rearing system, the nature of forage and the supplementation level. Hence, the objective of this study was the evaluation of the milk production and quality of *Sicilo-Sarde* ewes raised in feedlot or grazing green barley and perennial ryegrass. Sheep were divided into 4 groups. The stall (ST) group received ad-libitum hay and silage with 500g of concentrate. Two groups were grazed on green barley (B) and one on rye-grass (RG). Grazing was managed rotationally with a stocking rate of 25 ewes/ha. The RG group and one of the B groups (B-CC) were supplemented with 300g concentrate; the last group did not receive concentrate (B-C0). The average biomass production was 3.43 and 2.03 tons of dry matter (DM) per hectare for green barley and ryegrass, respectively. Total and daily milk production of ewes was significantly (P <0.001) higher for pasture groups than for the ST group. The daily milk yield was 349, 599, 647 and 592 ml/ewe, for ST, B-C0, B-CC and RG, respectively. Milk fat and protein content were significantly higher for ST than for the grazing groups (P <0.001), while fat and protein yields were higher for grazing groups than for the ST (47 vs. 32 g/d, respectively). As a conclusion, grazing improves milk production with a lower concentrate supply.

Keywords. Dairy ewes – Grazing – Feedlot – Milk production.

Production laitière de brebis conduites en bergerie ou pâturant de l'orge en vert ou du ray-grass

Résumé. *La production ovine laitière dépend de plusieurs facteurs tels que le mode de conduite, la nature du fourrage et le niveau de supplémentation. L'objectif de ce travail était l'étude de la production laitière quantitative et qualitative des brebis Sicilo-sarde à l'auge ou en pâturage. Un troupeau de brebis de race Sicilo-sarde a été réparti en 4 lots homogènes, un lot en bergerie recevant foin et ensilage à volonté, 2 lots pâturant l'un de l'orge en vert et l'autre du ray-grass avec un chargement de 25 brebis par ha. La conduite du pâturage était en rotation. Le pâturage de l'orge en vert s'est prolongé du 22 décembre au 16 Mars (durée totale 86 jours), celui du ray-grass du 22 décembre au 5 avril (durée totale 106 jours). La complémentation a été de 500g d'aliment concentré dans le lot de bergerie (Berg), de 300 g dans le lot de ray-grass (RG) et un des lots d'orge (O-CC) et de 0 g dans l'autre lot d'orge (O-C0). La production de biomasse était en moyenne de 3,43 et 2,03 tonnes de MS/ha respectivement pour l'orge et le ray-grass. La production laitière des brebis a été significativement (P<0,001) plus élevée au pâturage pour les deux espèces fourragères qu'en bergerie alors qu'elle n'a pas été affectée par la complémentation sur l'orge en vert. La production laitière journalière était de 349, 599, 647 et 592 ml, respectivement, en Berg, O-C0, O-CC et RG. Le lait produit en bergerie était significativement plus riche en MG et en MP que celui produit au pâturage, alors que la quantité totale de MG et MP était plus élevée au pâturage qu'en bergerie (47 vs 32 g/j, respectivement). Ainsi, le pâturage permet une meilleure production laitière avec un plus faible apport d'aliment concentré.*

Mots-clés*. Brebis laitières – Pâturage – Bergerie – Production laitière.*

I – Introduction

In Tunisia, dairy sheep farming uses mainly the *Sicilio-Sarde* breed, which is exploited for milk and meat production. Dairy sheep farms are located almost exclusively in the sub-humid region of the country (*Beja* and *Bizerte*) where climatic conditions are favorable for grassland and forage pro-

duction (Atti and Rouissi, 2003). However, the feeding management of dairy sheep remains extensive and traditional : lactating ewes are fed on fallows, stubbles and crop residues with low supplementation in concentrated feed. In big farms, dairy ewes are either fed on hay and silage, or on grazed green barley. In both cases, concentrate supplementation is important, whatever the level of milk production or the forage ration (Toukebri, 1998). Improving the productivity of this breed requires a thorough knowledge of its production potential in the local environment. Among the factors likely to influence milk production of ewes, feeding can be considered as the most important. The objective of this work was to study the quantitative and qualitative milk production of *Sicilo-Sarde* ewes fed in stall or in direct grazing green barley or ryegrass pastures.

II – Material and methods

The study was conducted in winter-spring, at the dairy experimental farm "*Lafareg, Beja*" of the National Institute of Agronomic Researches of Tunisia (INRAT). This trial lasted almost four months (22 December – 5 April).

1. Animals and diets

100 lactating Sicilo-Sarde ewes (10 weeks of lactation) were divided into 4 groups. The stall-fed (ST) group received ad-libitum hay and silage with 500g of concentrate. Two groups were conducted on green barley (B) and one on ray-grass (RG), grazing at a stocking rate of 25 ewes/ha. The RG group and one B group (B-CC) were supplemented with 300g of concentrate; the last group did not receive concentrate (B-C0).The pasture assigned to each group was divided in different paddocks. When the grazing height became as low as 7 cm, ewes changed paddock and so forth.

2. Milk control and analysis

Ewes were milked daily at 07:30 and 16:30 during all the experimental period. Individual milk yield was recorded weekly during the whole observation period and individual milk samples (20 ml) were kept cool (4°C) and analyzed for milk fat (F) and protein (P) using a MilkoScan 4000 (FOSS ELECTRIC, Integrated Milk Testing) at the breeding center of Livestock and Pasture Office in *Sidi-Thabet*.

III – Results and discussion

1. Biomass production

During the experimental period, green barley sown in late October, was exploited relatively early in the season (December 22) with a biomass production of about 3.43t of dry matter (DM) / ha allowing only two passages. Ryegrass had a fairly low production compared to barley (2.03t DM/ha), allowed more than two passages and was characterized by a very high biomass in late April (5.67 t DM / ha).

2. Milk yield and composition

The average milk yield and fat and protein contents observed during the experimental period are reported in Table 1.The daily milk yield was significantly ($P < 0.001$) affected by the rearing system, averaging 613 vs. 363 ml/d for ewes fed at pasture or in stall, respectively.

Considering the forage species, milk yield was slightly higher for barley (623 ml/d) than for ryegrass (592 ml/d), but the difference was not significant. This result (higher milk yield for green cereal compared to typical forage species) is similar to those of Atti and Rouissi (2003) who compared barley to vetch but does not agree with those of Gafsi (2003) who compared oats to phalaris. Among

groups grazing green barley, even though the milk yield was lower for the group without concentrate supplementation (599 ml/d vs 647 ml/d), the difference was not significant. When grass availability is ggod, the response to supplementation is low (Delaby *et al.,* 2003). Therefore, the supplementation of *Sicilo-sarde* sheep at pasture does not always affect milk production (Ligios *et al.,* 2002, Atti and Rouissi, 2003).

The milk produced by stall-fed ewes contained significantly higher fat (P <0.001) and protein (P <0.001) than that produced at pasture (Table 1). This can be explained by the higher concentrate supplementation in stall: an increased concentrate level causes at all stages of lactation a significant increase in the fat and protein levels (Bocquier *et al.,* 2002).The effect of dilution (Othmane *et al*., 2002) associated to a greater milk production in grazing groups compared to ST could also explain this result. However, milk fat and protein yields (in gram per day) were higher in both grazing groups than in ST (Table 1).

Table 1. Average milk yield and composition of dairy ewes (ST: The stall-fed group received ad-libitum hay and silage with 500g of concentrate; B-C0: the group that grazed on green barley (B) and did not received concentrate; B-CC: the group that grazed on green barley (B) and complemented with 300g of concentrate; RG: the group that grazed on rye-grass (RG) and complemented with 300g of concentrate)

	ST	B-C0	B-CC	RG	P
Milk yield (ml/day)	363^{b}	599^{a}	647^{a}	592^{a}	***
Fat (g/kg)	86,8^{a}	75,5^{b}	76^{b}	76,9^{b}	***
Fat (g/day)	32^{b}	45^{a}	49^{a}	46^{a}	***
Protein (g/kg)	56,5^{a}	53,8^{b}	53,9^{b}	51,7^{b}	***
Protein (g/day)	21^{b}	32^{a}	35^{a}	31^{a}	***

***p<0.001.

IV – Conclusions

Ewes fed at pasture consumed less concentrate but produced more milk than stall-fed sheep. According to the forage species, milk production was similar for green barley and ryegrass pastures. With green barley, at this stocking rate and for this level of milk production, concentrate supplementation was not required for *Sicilo-Sarde* ewes. We can encourage the management of dairy sheep on ryegrass, provided that the supplementation is well adjusted. The latter must be used in a suitable way, according to pasture type, biomass availability, level of milk production. During the rainy days where the ewes do not go out at pasture, conserved feed should compensate for the forage shortage.

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Parallel Session 1 (Nutrition Subnetwork)

Nutritional strategies to improve sheep and goat adaptation and production efficiency

Smart feeding for improved performances and meat and milk quality of small ruminants

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Abstract. The drylands are home to large flocks of sheep and goats but do not produce sufficient feedstuffs to overcome the nutritional requirements of livestock. This situation is exacerbated by the impacts of climate change, in particular through the quantitative and qualitative decrease contribution of forage and range vegetation to the diets of these animals. Therefore, the production cost is continuously increasing and the sustainability of livestock production systems is threatened. Producing more with minimum inputs has become a challenge for livestock breeders. Some affordable feeding technologies and practices hold promise to tackling such objective. For example, infrequent nitrogen supplementation did not compromise livestock performance and maximized cost efficiency. Some locally produced feed resources had been efficient in replacing common and expensive feed sources, mainly concentrate feeds in sheep and goat diets. Appropriate watering is a prerequisite to optimize feeding efficiency. Natural additives phytochemicals are investigated as potential substitutes to enhance livestock production. This is mainly referring to plants, plant extracts and or natural plant compounds (e.g. tannins, saponins, essential oils, etc.). These alternative feeding options had increased feeding efficiency, production performance and or meat and milk quality. A range of plants are a valuable source of phytochemicals such as vitamins, polyphenols, minerals, fibre, unsaturated fats that show antioxidant, antimicrobial, anticholesterolemic and other positive biological activities in humans. It has been estimated that 30% of the plant material processed by the food industry is discarded as non-human edible waste. In a global context characterized by a growing pressure for increasing the sustainability of production systems, including agro-industrial by-products (AIBP) in the diet of farm animals represents a strategy to mitigate the environmental impact of livestock production, especially for ruminants. In particular, the dietary administration of AIBP to replace feeds traditionally included in the animal feeding such as, cereals and pulses, could reduce the competition between feed and food. Moreover, during the last years, research showed that the inclusion of AIBP and some plants containing secondary compounds in the ruminant diet may have positive effects on animal health and can improve the nutritive value and the shelf-life of milk and meat. However, discontinuous availability during the year, unbalanced chemical composition and the presence of antinutritional factors represent critical issues that need to be evaluated to effectively exploit these novel feeds. This review presents and discusses the recent findings on smart feeding as cost-effective and environment friendly option to reiterate the importance of livestock breeding in production systems that are exposed to climate change.

Keywords: Smart feeding – Production performance – Milk – Meat – Ruminants.

Une alimentation intelligente des petits ruminants pour de meilleures performances et une meilleure qualité de la viande et du lait

Résumé. *Les terres arides abritent de grands troupeaux d'ovins et de caprins, mais ne produisent pas suffisamment pour satisfaire les besoins nutritionnels des animaux. Cette situation est encore exacerbée par les impacts du changement climatique, surtout en raison de la diminution de la part, quantitative et qualitative, de fourrage et de végétation des parcours dans l'alimentation de ces animaux. Par conséquent, le coût de production augmente continuellement et la durabilité des systèmes de production animale est menacée. Produire plus avec un minimum d'intrants est devenu un défi pour les éleveurs. Cependant certaines technologies et pratiques alimentaires à coût abordable sont prometteuses pour affronter cet objectif. Par exemple, une supplémentation en azote peu fréquente n'avait pas compromis les performances des animaux et avait maximisé l'efficience relativement au coût. Certaines ressources alimentaires produites localement avaient été efficientes pour remplacer des sources classiques et onéreuses, en particulier les aliments concentrés pour régimes ovins et caprins. Une distribution d'eau appropriée est un pré-requis pour optimiser l'efficience alimentaire. Certains additifs phy-*

tochimiques naturels font l'objet d'études comme substituts potentiels pour améliorer la production animale. Ceci concerne principalement les plantes, extraits de plantes et/ou composés naturels de plantes (p.ex. tannins, saponines, huiles essentielles, etc.). Ces options alternatives avaient augmenté l'efficience alimentaire, les performances productives et/ou la qualité de la viande et du lait. Il existe une vaste gamme de plantes qui sont une source précieuse de phytochimiques tels que vitamines, polyphénols, minéraux, fibre, graisses non saturées, montrant chez les humains des propriétés antioxydantes, antimicrobiennes, anticholestérolémiques et autres activités biologiques positives. Il est estimé que 30% du matériel végétal transformé par l'industrie alimentaire est rejeté comme résidu non apte à la consommation humaine. Dans un contexte global caractérisé par une pression grandissante afin d'augmenter la durabilité des systèmes de production, le fait d'inclure des sous-produits agro-industriels (SPAI) dans le régime des animaux de ferme représente une stratégie pour atténuer l'impact environnemental de la production animale, spécialement chez les ruminants. En particulier, la distribution de SPAI pour remplacer les matières traditionnellement incluses dans les régimes animaux, telles que céréales et légumineuses, pourrait réduire la concurrence entre alimentation humaine et animale. De plus, lors des dernières années, la recherche a montré que l'inclusion de SPAI et de certaines plantes contenant des composés secondaires dans la diète des ruminants pourrait avoir des effets positifs sur la santé animale et peut améliorer la valeur nutritive et la durée de conservation du lait et de la viande. Toutefois, la disponibilité discontinue au cours de l'année, la composition chimique non équilibrée et la présence de facteurs antinutritionnels représentent des problématiques critiques qu'il faut évaluer pour exploiter efficacement ces nouvelles matières alimentaires. Cette révision présente et examine les résultats récents sur l'alimentation intelligente en tant qu'option coût-effective et environnementalement respectueuse, en soulignant l'importance de l'amélioration animale dans les systèmes de production exposés au changement climatique.

Mots-clés. *Alimentation intelligente – Performances productives – Lait – Viande – Ruminants.*

Replacement of soybean meal with lupine in Barbarin lamb diet: Effect on intake, digestion, fermentation and growth

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Abstract. This study aims to evaluate the effect of white lupine seeds as a substitute for soybean meal in the diets of lambsTwenty-four 6 and a half month-old Barbarine lambs (average initial weight 23 kg) were divided into three equal groups. Three types of concentrates, the first two of which were iso-nitrogenous, were formulated as follows: CC1 containing 75% barley, 22.5% soybean meal and 2.5%mineral and vitamin supplement (CMV); CC2 containing lupin as a substitute for soybeans; and CC3 containing only barley and CMV (this is the concentrated 1 devoid of soybean meal). In addition to the hay that was distributed at libitum, animals assigned to the first and the second group received daily, 500 g of concentrate 1 and 500g of concentrate 2, respectively. Those assigned to the third one received alternately concentrate 2 (day1) and concentrate 3 (day2). Experiment period was divided in a growth period (80 days) followed by a digestible period (10days). Diet had no significant effect on total dry matter and water intakes, average daily gain, diet digestibility and microbial synthesis ($P > 0.05$). For the nitrogen balance, the animals showed different retained nitrogen level ($P < 0.05$). Fermentation parameters were not affected by protein source. However, only the number of protozoa was influenced by the day of fluid collection ($P < 0.05$). It can be concluded that lupine grains can substitute safely soybean meal in diets of Barbarine lambs.

Key words: Soybean meal – Lupine – Lambs – Intakes – Digestibility – Fermentation – Average daily gain.

Remplacement du tourteau de soja par lupin dans l'alimentation des agneaux barbarins: Effet sur l'ingestion, digestibilité, fermentation et la croissance

Résumé. *L'objectif de cette étude est l'évaluation de l'effet de l'utilisation des graines de lupin blanc dans l'alimentation des agneaux comme un substitut au tourteau de soja. Pour cela, vingt-quatre agneaux de la race Barbarine, ayant un poids moyen de 23 kg et âgés en moyenne de 6 mois et demi divisés en trois lots homogènes. Trois types de concentrés, dont les deux premiers sont iso-azotés, ont été formulés comme suit : CC1 contenant 75 % orge, 22.5 % tourteau de soja et 2.5 % CMV ; CC2 contenant le lupin en remplacement avec le soja ; et CC3 contenant seulement de l'orge et de CMV. En plus du foin distribué à volonté, les animaux des deux premiers groupes ont reçu quotidiennement 500 g du concentré 1 (et 500 g du concentré 2, respectivement. Ceux du troisième goupe ont reçu en alternance le concentré 2 (jour1) et le concentré 3 (jour2). Les animaux ont subi une période de croissance (80 j) suivie par une période de digestibilité (6j). Les résultats obtenus ont montré que le régime alimentaire n'avait pas d'effet significatif sur les quantités ingérées, la consommation d'eau, le gain quotidien moyen, la digestibilité du régime et la synthèse microbienne ($P > 0.05$). Le bilan azoté qui était positif a varié significativement entre les trois lots ($P < 0.05$). Le pH, le nombre de protozoaires et le taux d'ammoniac les plus élevés ont été affectés par les régimes. Seulement le nombre de protozoaires qui a été influencé par le jour du prélèvement ($P < 0.05$).*

Mots-clés. *Tourteau de soja – Lupin– Agneau – Ingestion – Digestibilité – Fermentation – Gain quotidien moyen.*

I – Introduction

In Tunisia, particularly in the arid and semi-arid zones, climatic conditions have caused the degradation of rangelands leading to a forage deficit, particularly in sheep and goats. Thus, energy and / or nitrogen supplementation has become essential to maintain these animals and ensure the expected performance. For this reason, Tunisia has resorted to the import of raw materials including soybean meal, barley and corn (Ben Salem, 2011). However, fluctuations in their prices on the world market are negatively affecting animal nutrition industry. Our country imports annually, over 300,000 tons of soybean meal at a price of 1.2dt / kg (Bahri *et al*., 2014). Similarly, these imported raw materials are unstably available on the Tunisian market which can affect the profitability of farms and alter the sustainability of animal production sector. As a result, several attempts to replace these foods, including soybean meal, have been considered by researchers. Protein crops (Lupine, faba beans...) are good alternatives to soybean meal because of their high crude protein content. However, despite their good nutritional quality, their use in animal nutrition is currently limited due to the presence of anti-nutritional factors (Faba bean tannins, lupine alkaloids ...) and their fluctuating availability on the market. Thus, the main objective of this study is the evaluation of the substitution effect of soybean meal by sweet lupine on the ingestion, digestion, growth in Barbarine lambs.

II – Materials and methods

1. Animals

24 six-month-old Barbarine lambs were selected (23 kg±0.32). They were acclimated for 4 days to new housing conditions. Lambs were weighed than divided into three equal groups. All animals received oat hay *ad libitum* and concentrate. the first group received CC1 containing 75% barley, 22.5% soybean meal and 2.5% CMV, where as the second received CC2 containing lupine as a substitute for soybeans in term of CP to be iso-nitrogenous with CC1. The third group received alternately CC2 and CC3 containing only barley and CMV. Experiment period lasted 90days divided in a growth period (80 days) and digestible period (10 days).

2. Sampling

Average daily growth was assessed through weighing animals biweekly. At digestible period, lambs were housed in metabolic cages. A 7-day faecal collection period started on the following day. After weighing the amounts of fresh feed, refusals and faeces, samples of each were taken daily. Part of each sample was used for DM determination and the other part (20% of the weight of the fresh refusals and faeces) was stored at 4 ºC for hay and concentrates or at – 5 ºC for faeces. Urine was collected in plastic recipients containing 100 ml of a 10% sulphuric acid solution (v/v) and frozen (– 20 ºC). Pooled samples of individual feed refusal, and faeces were dried at 50 ºC, ground through 1 mm screen to be analysed. Samples of urine were stored in the freezer (– 20 ºC) until analysed. At the end of the growth period, rumen fluid was taken in two consecutive days to measure pH and ammonia content and to determine protozoa number.

3. Analyses

Feed, refusals and faeces samples were analysed for dry matter (DM), ash and crude protein (AOAC, 1984). They were analysed for (NDF, ADF and ADL) (Van Soest *et al*., 1991). Urine was analysed for Kjeldahl nitrogen (AOAC, 1984) and allantoin concentrations(Chen and Gomes, 1992). Rumen fluid samples were were analyzed for NH3-N (Weatherburn, 1967).

III – Results and discussion

Table 1 reports nutrient contents of feeds. soybean meal is greater in CP than lupine, while the opposite trend was observed for NDF, ADF and ADL.

Table 1. Chemical of the experimental feeds (g/kg DM)

	Oat hay	Soybean meal	Lupin	Barley
DM	929	903	903	896
OM	915	932	967	974
CP	77.6	480	329	110
NDF	673	172	270	489
ADF	404.3	52.9	151.6	102.2
ADL	62.5	3.75	8.63	25.9

Diets intake and digestibility are shown in Table 2. Results revealed that additional protein source did not affect intake, which corroborates with results reported by El Maadoudi (2004) and Ephrem *et al*. (2015). This could be explained by the importance of the nutritional quality of protein sources. Nevertheless, our results are contradictory to those reported by Lestingi *et al*. (2015) by testing the replacement of peas. In addition, proteins source did not reveal a significant effect on digestibility. DCPi amount was significantly affected (P< 0.01). Purroy *et al.* (1989) observed significant differences in diet digestibility by replacing soybean meal with lupine in lambs. Lupine incorporation improved diet digestibility (Ephrem *et al*., 2015). Lupine had no significant effect on the average daily gain (ADG). This result agrees with those of trials carried out on the replacement of protein seeds by lupine (El Maadoudi and El Housni, 2013, El Otmani *et al*., 2011). Moreover, Facciolongo *et al*. (2014) found that supplementation with soybean meal and lupine induced similar ADG, while Lestingi *et al*. (2015) showed low weight gain in animals fed lupine. Although the 3rd group received half of the quantity of lupine consumed by the 2nd one, the corresponding lambs were able to have similar and even better ADG than the others. This leads us to think about the concept of food efficiency. It seems that these animals were able to optimize their efficiency to transform food resources into meat.

Table 2. Effect of of lupine on intake, diets digestibility and daily gain in lambs

	Diets			ESM	P-value
	1	2	3		
DM intake (g/kg BW$^{0.75}$)					
Hay	50.9	50.5	53.0	2.56	0.7639
Diet	84.1	85.0	82.3	2.73	0.7695
Digestibility (%)					
DM	68.9	68.4	68.8	1.02	0.9294
OM	71.0	70.4	70.9	0.98	0.8896
CP	70.5	70.7	68.9	1.11	0.4831
NDF	67.2	65.5	65.2	1.19	0.4592
Intake (g/kg BW$^{0.75}$)					
DOM	55.6	55.7	54.0	1.68	0.7227
DCP	7.96^{a}	8.23^{a}	6.84^{b}	0.20	0.0003
Average daily gain. g/day	99.91	82.14	101.3	6.39	0.0835

^{a,b} Means in the same line with different superscripts are significantly different (P < 0.05).

Nitrogen balance and microbial synthesis are shown in Table 3 . It appears that all animals had positive balances. However, a significant variation in the amount of nitrogen intake and retention was observed in the 3rd group in comparison with the two others. This difference is explained by the variation of the ingested quantity of the concentrate. By correcting the retained nitrogen to the nitrogen intake, the nitrogen balance was similar for all diets, which confirms that animals had the same nitrogen use efficiency. Moreover, similar CP digestibility reinforces this finding.

Total amounts of purine and microbial nitrogen were not influenced by supplemented proteins (P> 0.05), which is consistent with the lack of effect on the CP digestibility. In accordance with our results, Yu *et al*. (2002) found no significant differences between purine and microbial nitrogen in lambs supplemented or not with blue lupine or faba beans.

Table 3. Effect of supplementation of lupine on nitrogen balance and microbial N supply in lambs

	Diets			ESM	P-value
	1	2	3		
Nitrogen intake (Ni), g/day	23.1[a]	23.0[a]	20.3[b]	0.42	0.0001
Fecal N, g/d	7.43	7.37	6.99	0.39	0.6875
Urinary N, g/d	4.18	4.16	3.71	0.49	0.7475
Retained N, g/d	11.5[a]	11.5[a]	9.6[b]	0.49	0.0176
Retained N, % Ni	49.7	49.9	47.6	2.41	0.7636
Total purine (mmol/d)	13.3	13.2	14.0	0.69	0.6668
Microbial N, g/d	9.70	9.57	10.2	0.50	0.6660

[a,b] Means in the same line with different superscripts are significantly different (P < 0.05).

Table 4 presents fermentation parameters. Average pH was affected by the diet (P < 0.05). pH corresponding to the 2nd group exceeded significantly that of the 1st group, but no significant difference was detected between that of the 3rd group and the others. Brand *et al*. (1999) reported pH values ranged between 6.4 and 6.3 in castrated rams fed a lupine diet. Ammonia level was affected only by diet (P > 0.05). The highest concentration was observed in daily lupine fed lambs. White *et al*. (2002) found that ammonia concentration were higher with lupine incorporation rate of 70% than with 35%, which corroborates the high ammonia level in animals receiving lupine daily and the low one in animals receiving lupine alternately. Protozoa numeration revealed a significant difference between diets. Animals belonging to the 2nd group had the highest number whereas those of the 3rd group had the lowest one. This could be explained by the corresponding ammonia concentrations since a large protozoa population is generally associated with a high ammonia concentration (Thivend *et al*., 1985).

Table 4. Effects of lupine on pH, ammonia nitrogen (mg/dl) and protozoa number (×10^5/ml)

	Day		Diets[1]			S E M		P-value		
	1	2	1	2	3	Day	Diet	Day	Diet	day*diet
pH	6.1	6.2	6.1[a]	6.2[b]	6.1[ab]	0.02	0.03	0.114	0.001	0.660
Protozoa	12.4	15.1	14.4[ab]	15.3[a]	11.7[b]	0.67	0.82	0.005	0.008	0.955
NH_3-N	20.5	19.9	19.9[a]	23.9[b]	16.8[a]	0.79	0.97	0.587	<.001	0.114

[a,b] Means in the same line with different superscripts are significantly different (Pr < 0.05).
SEM: Standard error of the mean.

IV – Conclusions

It can be concluded that lupine grains can substitute safely soybean meal in diets of Barbarine lambs.

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In vitro fermentation and acidification potential of several carbohydrates sources used in concentrate-based diets for growing ruminants

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Abstract. This *in vitro* work aims to study how the different carbohydrate sources fed during the fattening of young ruminants can modulate the characteristics of ruminal fermentation. Six carbohydrate feeds (barley, B; maize, M; sorghum, S; sugarbeet pulp, BP; citrus pulp, CP; and wheat bran, WB) were tested in an *in vitro* semi-continuous culture system under a poorly buffered medium from 0 to 6h, and allowed pH to rise to around 6.5 from 8 to 24h. Rumen fluid was obtained from three lambs fed *ad libitum* on a diet composed of concentrate and barley straw. The pH from 2 to 12h was reduced at a higher extent with CP, which recorded its minimum value at 6h (5.60; P<0.05), but recovered thereafter to 6.63 at 24h. During the whole incubation period, the volume of gas recorded with CP was the highest (P<0.05), followed by B and WB, whereas the lowest volume was recorded by S. Gas production results were supported by dry matter disappearance (DMd) at 24h. Concentration of volatile fatty acids (VFA) and lactic acid was the highest with CP (P<0.05), followed by WB and B. A higher acetate proportion was observed with BP and CP (P<0.05) that recorded the lowest butyrate proportion. Regarding microbial diversity, after 8h, within each incubation series substrates clustered together, except for CP and WB. CP acidified the incubation medium in a higher extent, followed by WB and B. The capacity of substrate acidification plays an important role on dynamics of *in vitro* microbial fermentation.

Keywords. Carbohydrates – Ruminal fermentation – Gas production – pH – *In vitro* semi-continuous culture system.

Fermentation* in vitro *et potentiel d'acidification de quelques sources de glucides utilisées dans les régimes à base de concentrés pour les ruminants en croissance

Résumé.*Ce travail* in vitro *avait pour objectif d'étudier comment les différentes sources de glucides utilisées lors de l'engraissement des jeunes ruminants peuvent moduler les caractéristiques de la fermentation ruminale. Six aliments glucidiques (orge, B; maïs, M; sorgho, S; pulpe de betterave, BP; pulpe d'agrumes, CP; et son de blé, WB) ont été testés dans un système in vitro de culture semi-continue sous un milieu faiblement tamponné de 0 à 6h, et ajusté à un pH d'environ 6,5 á partir de 8h. Le liquide ruminal provenant de trois agneaux recevant ad libitum une ration composée de concentré et de paille d'orge . De 2 á 12h, le pH a fortement chutéavec CP qui a enregistré la plus faible valeur á 6h (5,60; P<0,05), mais ensuite le pH a augmenté pour atteindre 6.63 á 24h. Durant toute la periode d'incubation, le volume de gas enregistré avec CP a été le plus élevé (P<0,05), suivi par B et WB, alors que le volume le plus bas a été enregistré avec S. Les résultats de la production de gaz ont été soutenus par la disparition de la matière sèche (DMd) á 24h. Les concentration des acides gras volatiles (VFA) et d'acide lactique ontété supérieures avec CP (P<0,05), suivi par WB et B. Une proportion élevée d'acétate a été observée avec BP et CP (P<0,05) qui ont enregistré la proportion la plus basse de butyrate. En ce qui concerne la diversité microbienne, après 8h, au sein de chaque série d'incubation les substrats ont été regroupés, à l'exception du CP et WB. La CP a acidifié davantage le milieu d'incubation, suivi par WB and B. La capacité d'acidification du substrat joue un rôle important dans la dynamique de la fermentation microbienne* in vitro.

Mots-clés. *Glucides – Fermentation ruminale – Production de gaz – pH – Système* in vitro *de culture semi-continue.*

I – Introduction

A wide array of carbohydrate sources, varying in composition, is currently used as energy sources in ruminant diets. Cereal grains are high starch sources, which availability differs according to its chemical structure, protein matrix or presence of phenolics (O´Brien, 1999; Offner *et al*., 2003), whereas other substrates are fermentable fibre sources, with either insoluble (cellulose, hemicelluloses) or soluble (mostly pectin) polysaccharides, and also containing variable proportions of either starch or sugars. Fitting substrate characteristics to the fermentative ability of rumen microbiota, when the environmental conditions are maintained under an optimal range is a key factor for maximising energy utilisation in ruminants, thus the risk of physiological impairment is reduced. Whereas their study *in vivo* is often biased by hardly controlled fermentation conditions such as passage rate, *in vitro* techniques are widely used for obtaining a good insight into rumen fermentation processes. However, most of these *in vitro* methods are designed for mimicking high forage diets, and it is not easy to adapt some main physiological conditions such as pH and rate of passage to the environment promoted by high concentrate diets. Using a simple semi-continuous incubation system (Fondevila and Pérez-Espés, 2008), and applying the procedure proposed by Amanzougarene and Fondevila (2018) for controlling incubation pH, in this work several carbohydrate sources with varying composition were compared in terms of ruminal fermentation pattern, simulating the rumen pH and the liquid outflow rate to conditions of intensive feeding systems.

II – Materials and methods

Six carbohydrate sources, namely three cereal grains, barley (var. Gustav, B); maize (var. Dekalb 6667Y, M); and a brown sorghum (S) and three fibrous feeds, sugarbeet pulp (BP); citrus pulp (CP); and wheat bran (WB) were tested in three incubation series of 24h. Substrate samples (800 mg) were dispensed into nylon bags (45 µm pore size) that were sealed and introduced in duplicated bottles filled under CO_2 flux with 80 mL of incubation solution including 16 mL thawed inoculum (0.20 of total volume). As donor of rumen inoculum, three growing lambs weaned at 7 weeks ± 8 days were fed *ad libitum* for 35 days to obtain the adequate inoculum characteristics, and then were slaughtered. A ration was composed by a standard concentrate (barley, maize, wheat, and soybean meal) plus barley straw. Concentrate and straw were fed *ad libitum* allowing for 0.10 daily refusals. The rumen contents of each animal were filtered through a cheesecloth, immediately frozen in liquid nitrogen and preserved at –80 ºC until using. Immediately before incubation, rumen inoculum was thawed in a water bath at 39ºC. Two buffer solutions were made up, one with 0.006 M bicarbonate in order to get a poorly buffered medium pH (≈5.5) for being used from 0 to 6h incubation, and another with 0.058 M bicarbonate to fitting medium pH around 6.5 for being used from 8 to 24h incubation (Amanzougarene and Fondevila, 2018). Pressure produced on each bottle was measured every 2h (from 0 to 12h) or every 4h (from 12 to 24h), and gas volume was expressed per unit of incubated organic matter (OM). Along the incubation, a volume of liquid medium was extracted immediately after gas measurement, and replaced anaerobically by the same volume of incubation solution (without microbial inoculum) to simulate an approximate liquid turnover rate of 0.08/h. Incubation pH was recorded on every extraction, and medium was sampled at 6, 10 and 24h and immediately frozen until determination of volatile fatty acids and lactic acid concentrations, or sampled at 8h and frozen in liquid nitrogen for microbial biodiversity by terminal restriction fragment polymorphism (tRFLP). At the end of incubation, bags with the substrate residue were removed, rinsed and dried at 60ºC for 48h for determination of dry matter disappearance (DMd).

The microbial diversity results were analysed with R statistical software in the form of relative abundance. Results of the different substrates were analysed by ANOVA using the Statistix 10 software package, considering the incubation series as a block (n=3), and the incubated bottles as the experimental unit. The differences were considered significant when $P<0.05$. The Tukey *t* test ($P<0.05$) was used for the multiple comparison between means.

III – Results and discussion

The mean inoculum pH at the start of the incubation series was 6.45 ± 0.15. The lowest pH was recorded at 6h of incubation (5.96 ± 0.19), and afterwards it increased to reach an average of 6.64 ± 0.02 at 24h, showing that rumen pattern can be simulated *in vitro* by changing buffer concentration, as planned (Fig. 1a). Among substrates, from 2 to 12h CP recorded the lowest incubation pH ($P<0.05$), reaching its minimum at 6h (5.60; $P<0.05$), but it recovered thereafter to 6.63 at 24h. S, BP, and M maintained the highest medium pH ($P<0.05$) from 4 to 8h. Regarding the gas production, CP recorded the highest volume throughout all the incubation period (Fig. 2a, $P<0.05$), and the lowest volume was recorded by S. Similar to the gas production results, DMd was highest for CP (0.513), and the lowest DMd was shown with S (0.251; $P<0.05$, SEM=0.0178).

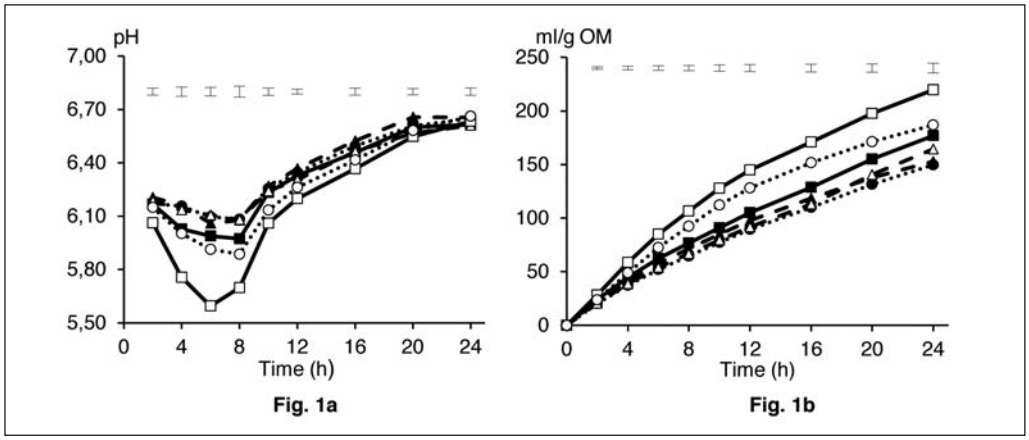

Fig. 1. Pattern of incubation pH (Fig. 1a) and gas production (Fig. 1b) (B ■, CP □; solid line, M ▲, BP △; dashed line , S ●, WB ○; dotted line). Upper bars show standard error of means (n=3).

Similarly, these results were supported by those observed in concentration of VFA and lactic acid. Thus, at 6h incubation, the highest concentration of lactic acid was recorded with CP (8.70 mmol/L; $P<0.05$) compared to the other substrates (2.40 mmol/L, on average). A similar trend was observed on the VFA concentration. As it is shown in Table 1 for results observed at 24h,the highest total VFA concentration was recorded by CP, and the lowest was showed by M and S ($P<0.05$). The heterogeneous chemical nature of substrates was reflected through a higher proportion of acetate ($P<0.05$) with BP and CP at the expense of butyrate, probably because of their higher content of rapidly fermentable fibre and pectin. The highest butyrate proportion was recorded with M and the lowest was observed with BP ($P<0.05$) whereas no differences were recorded on propionate proportion. Results from bacterial biodiversity after 8h of incubation (Fig. 2) were markedly affected by the incubation series (that is, the donor animal). Apart of this, within each incubation series substrates clustered together except for CP (series 2 and 3) and WB (series 1), which means that the characteristics of these byproducts might lead to a shift in bacteria diversity.

These results showed that citrus pulp has an acidic capacity of even higher magnitude than the other substrates because of its richness in both soluble fibre and soluble sugars (Barrios-Urdaneta *et al*., 2003). Despite the important proportion of pectin in sugarbeet pulp, a larger drop in medium pH was observed with citrus pulp or even wheat bran. Shahmoradi *et al*. (2015) reported that the sugarbeet pulp could affect positively ruminal pH. Among cereal species, despite the high proportion of starch in maize and sorghum (Amanzougarene *et al*., 2018), the structure of the starch endosperm of these species and the proportion of amylose (Offner *et al*., 2003) makes that, as expected, the starch of barley was degraded faster.

Table 2. Total volatile fatty acids concentration (VFA, mM) and molar proportions (mmol/mmol) of acetate (C2) propionate (C3) and butyrate (C4) at 24h for the different carbohydrates

Sub.	VFA	C2	C3	C4
B	21.4^{ab}	0.512^{b}	0.248	0.161^{ab}
M	14.9^{c}	0.509^{b}	0.239	0.164^{a}
S	17.5^{bc}	0.496^{b}	0.28	0.150^{ab}
BP	19.5^{abc}	0.632^{a}	0.234	0.090^{b}
CP	22.2^{a}	0.616^{a}	0.123	0.205^{ab}
WB	18.4^{abc}	0.517^{b}	0.134	0.266^{ab}
SEM	0.939	0.014	0.0236	0.0148

Means within a column with different superscripts differ (P<0.05).
SEM: standard error of means.

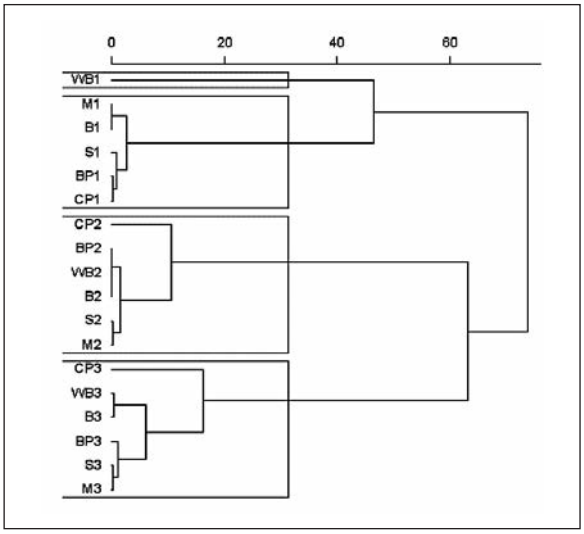

Fig. 2. Dendrogram of bacteria diversity at 8h. Scale bar shows Euclidean distances, "ward method".

IV – Conclusions

Under fermentation conditions of high concentrate feeding, some sources of highly fermentable fibre, such as citrus pulp and at a lower extent wheat bran, may create a more acidic environment than cereal grains. The *in vitro* semicontinuous system may be useful for the study of microbial fermentation of intensive feeding conditions.

Acknowledgments

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Effects of the incorporation of ensiled sugar beet pulp in the diet on lambs fattening performance

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Abstract. The objective of this study was to evaluate the effect of the incorporation of different levels of ensiled sugar beet pulp (ESBP) in the diet on lamb fattening performance. Eighteen Moroccan synthetic breed lambs "Dman*Boujaad" (20.2±1.35 kg initial body weight) were randomly assigned to three homogenous groups of six each. Three diets, depending on the ESBP incorporation level, were tested: $T_{0\%}$ (0% ESBP, 30% wheat straw (WS), 30% sunflower meal (SM), 25% maize grain (MG) and 15% barley grain), $T_{15\%}$ (15% ESBP,30% WS, 30% SM and 25% MG) and $T_{30\%}$ (30% ESBP,30% WS, 30% SM and 10% MG). The fattening trial was lasted for 70 days after 7-day of adaptation period. Lambs were weighed at the beginning and at the end of the trial and fortnightly. Average daily gain (ADG), Feed conversion ratio (FCR) and feeding cost were determined. The ADG of lambs consuming 15% of ESBP ($T_{15\%}$; 201.5 g/d) was higher (P=0.0085) than $T_{0\%}$ (132.7 g/d) and $T_{30\%}$ (173.5 g/d). The feed conversion ratio (Kg DMI/Kg ADG) was 8.67, 5.6 and 6.65 for diets containing 0%, 15% and 30 % of ESBP, respectively. The feeding cost (Moroccan dirham (MAD)/kg ADG) was 26.4, 17.7 and 20.5 for $T_{0\%}$, $T_{15\%}$ and $T_{30\%}$, respectively. An incorporation of ESBP at 15% of DM in fattening lambs' diets improves fattening performances.

Keywords. Ensiled sugar-beet pulp – Lamb – Fattening.

Effet de l'incorporation de la pulpe de betterave ensilée dans la ration sur les performances d'engraissement des agneaux

Résumé. *L'objectif de cette étude était d'évaluer l'effet de l'incorporation de la pulpe de betterave ensilée (PBE) à différents dans le régime alimentaire sur les performances d'engraissement des agneaux. Dix-huit agneaux marocains de race synthétique "Dman * Boujaad" (20,2 ± 1,35 kg de poids vif initial) ont été répartis aléatoirement en trois groupes homogènes de six chacun. Trois régimes alimentaires, selon le niveau d'incorporation du PBE, ont été testés : $T_{0\%}$ (0% PBE, 30% paille de blé, 30% tourteau de tournesol (TTS), 25% maïs et 15% orge), $T_{15\%}$ (15% PBE, 30% paille de blé, 30% TTS et 25% maïs) et $T_{30\%}$ (30% PBE, 30% paille de blé, 30% TTS et 10% maïs). L'essai d'engraissement a duré 70 jours après une période d'adaptation de 7 jours. Les agneaux ont été pesés au début et à la fin du procès et tous les quinze jours. Le gain quotidien moyen (GMQ), l'indice de conversion (IC) (Kg matière sèche ingérée/ kg de GMQ) et le coût alimentaire (CA ; dirham marocain (MAD) / kg de GMQ) ont été déterminés. Le régime alimentaire a affecté significativement le GMQ (P = 0,0085). Les agneaux du $T_{15\%}$ ont réalisé une GMQ de 201,5 g/j, par contre ceux du $T_{0\%}$ et $T_{30\%}$ ont réalisé un GMQ, respectivement, de 132,7 g/jet 173,5 g/j. L'Indice de conversion était de 8,67, 5,6 et 6,65 respectivement pour $T_{0\%}$, $T_{15\%}$ et $T_{30\%}$. Le coût alimentaire était respectivement de 26,4 ; 17,7 et 20,5 pour $T_{0\%}$; $T_{15\%}$ et $T_{30\%}$. L'incorporation de la PBE à un niveau de 15% de MS dans les rations d'engraissement des agneaux améliore les performances d'engraissement.*

Mots-clés. *Pulpe de betterave ensilée – Agneaux – Engraissement.*

I – Introduction

In Morocco, the activity of small ruminant production is affected by many factors such the succession of drought years, the rainfall irregularity, as well as the overuse of the pastoral areas. This situation leads to a significant reduction of forage availability and therefore an increasing of supplementary feeding prices mainly during feed shortages periods. Faced to this situation, small ruminant-holders are forced to look for other alternative feeding resources such beet pulp silage. The incorporation of this latter in ruminant diets may provide an opportunity to reduce feeding costs and also constitute an alternative to the high cost of producing dehydrated pulp beet. In this regards, studies have shown that beet pulp silage has a high nutritional value (Martelli *et al*., 1999) which is comparable to barley grain (Murphy, 1986) and also has a positive effect on ruminal fermentation (Formigoni *et al*., 1993). The objective of this work was to evaluate the effect of the incorporation of different levels of ensiled sugar-beet pulp in the diet on performance of Moroccan synthetic breed lambs' fattening.

II – Material and methods

Eighteen Moroccan synthetic breed lambs "Dman*Boujaad" with initial weight of 20.2 ± 1.35 and age 120 ± 20.4 days were randomly assigned to three diets (Table 1), depending on the ensiled sugar beet pulp (ESBP) incorporation level: $T_{0\%}$ (0% ESBP, 30% wheat straw (WS), 30% sunflower meal (SM), 25% maize grain (MG) and 15% barley grain), $T_{15\%}$ (15% ESBP,30% WS, 30% SM and 25% MG) and $T_{30\%}$ (30% ESBP,30% WS, 30% SM and 10% MG). Diets are distributed as total mixed ration (TMR) twice daily (at 9h and 12h). All used diets are iso-energetic and iso-nitrogenous. The trial lasted 77 days including 7 days of adaptation.

Table 1. Ingredients and chemical composition of used diets

	Diet		
	$T_{0\%}$	$T_{15\%}$	$T_{30\%}$
Ingredients (%, Dry matter weight basis)			
Ensiled sugar beet pulp (ESBP)	0	15	30
Wheat straw	30	30	30
Barley grain	15	0	0
Maize grain	25	25	10
Sunflower meal	30	30	30
Chemical composition (% Dry matter)			
Dry matter	89.4	78.9	68.7
Organic matter	95.1	95.1	94.7
Ash	4.9	4.9	5.3
Crude protein	13.4	13.2	13.3
Neutral detergent fiber	41.8	45.1	50.3
Acid detergent fiber	30.5	33.1	36.7
Lignin	8.1	8.2	8.6
Fat	1.8	1.8	1.7

$T_{0\%}$: Diet containing 0% ESBP; $T_{15\%}$: Diet containing 15% ESBP; $T_{30\%}$: Diet containing 30% ESBP.

The intake amounts were determined daily. Animals were weighed before morning feeding, at the beginning and the end of the trial and every 15 days during the trial.

Free clean water and mineral block were available all the time.

The effect of incorporation of ESBP in the diet on final weight and average daily gain (ADG) was analyzed was analyzed by means of a one-way analysis of variance according to the model:

$Y_{ij} = \mu + a_i + \varepsilon_{ij}$ where a_i represents the diet effect and ε_{ij} the experimental error. The PROC GLM procedure of the SAS statistical package was used for the analysis. Comparisons among mean values were tested using the LSD test.

III – Results and discussion

1. Fattening performances

Initial and final live weights as well as ADG are presented in Table 2. The highest ADG (P=0.0085) was recorded in the lambs receiving the $T_{15\%}$ and $T_{30\%}$ diet. This superiority of ADG in lambs consuming ESBP diet may be explained by a good digestive utilization of the diet due mainly to high content of ESBP in digestible fibers (Cuvelier and Dufrasne, 2015).

The results obtained for both live weight and ADG are lower than those reported by Benbati *et al*. (2017) using dry beet pulp in the diet. This difference may be to the polysaccharides fermentation loss of energy during the ensiling process (Martelli *et al*., 1999).

Table 2. Fattening performance of lambs fed diets containing different levels of ensiled sugar beet pulp incorporation

	Diets			SEM	P
	$T_{0\%}$	$T_{15\%}$	$T_{30\%}$		
Initial body weight (kg)	19.6	19.8	21.1	–	–
Initial body weight (kg)	28.8	33.7	33.1	1.89	0.1683
Average daily gain (g/d)	132.7[b]	201.7[a]	173.5[a]	13.47	0.0085

$T_{0\%}$: Diet containing 0% ESBP; $T_{15\%}$: Diet containing 15% ESBP; $T_{30\%}$: Diet containing 30% ESBP; SEM: standard error of the mean; P: probability of the differences;
[a, b] Means with different superscripts are significantly different (P<0.05).

2. Intake, feed conversion and feeding cost

The intake, feed conversion ratio and feeding cost are shown in Table 3. The feed conversion ratio was 8.67, 5.6 and 6.65 kg DMI/ kg ADG for $T_{0\%}$, $T_{15\%}$ and $T_{30\%}$, respectively. This result can be explained by the fact that the ESBP inclusion in the diet improves the organic matter digestibility (Richardson *et al*., 2003) and therefore reduces the feed conversion and feeding cost. This latter was 26.36, 17.73 and 20.52 MAD/kg ADG for $T_{0\%}$, $T_{15\%}$ and $T_{30\%}$, respectively.

The feed conversion and feeding cost obtained in this experiment are superior to those reported by Benbati *et al*., (2017) using dry beet pulp incorporated at 0%, 30% and 60% of dry matter for fattening lambs with 5.5, 4.8 and 5.2, respectively.

Table 3. Intake, feed conversion and feeding cost of used diets containing different levels of ensiled sugar beet pulp

	Diet		
	$T_{0\%}$	$T_{15\%}$	$T_{30\%}$
Intake (kg DM/d)	1.13	1.11	1.13
Feed conversion (kg DMI/kg ADG)	8.67	5.60	6.65
Feeding cost (MAD/kg ADG)	26.36	17.73	20.52

$T_{0\%}$: Diet containing 0% ESBP; $T_{15\%}$: Diet containing 15% ESBP; $T_{30\%}$: Diet containing 30% ESBP; DMI: Dry matter intake; ADG: Average daily gain; MAD: Moroccan dirham (1 MAD = 0.09 €).

IV – Conclusions

The results of this work showed that the incorporation of ensiled sugar beet pulp at 15% in the fattening diets of lambs improves the fattening performance. However, further trials should be carried out increasing the proportion of ESBP inclusion in the diet and involving aspects related to carcass characteristics and meat quality in order to complete the obtained results of this study.

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Halophytes and grass pea as alternative fodder resources for rearing lambs on saline area. The case of Kerkennah archipelago

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Abstract. Mediterranean saline soils can be valuable sources of nutrients for livestock. In Kerkennah, the Tunisian archipelago, characterized by high soil salinity, halophytic vegetation could partially substitute cultivated roughages. Moreover, some autochthonous legumes, such as *Lathyrus sativus* could be used as a protein source instead of soybean meal. In this context, we studied the effects of feeding lambs on rangeland rich in halophytes on growth performances and carcass quality. Forty weaned female Queue Fine de l'Ouest lambs aged 153±32 days and with an average weight of 25.45±4.33 kg were assigned into two homogeneous groups (n=20).The first group was fed in feedlot with straw *ad libitum* (S).The second was reared on rangeland rich in halophytes (R) (*Suaeda mollis*, *Salsola longifolia*, *Medicago littoralis*, *Gasul nodiflorum*) with a stocking rate of 3.33 lambs/ha. R group and S group received respectively 300 and 500 g/head/day of concentrate containing 12% of the grass pea. After 3 months, lambs were slaughtered at 33 kg. The average daily gain (ADG) was similar between groups (P> 0.05) (92 *vs.* 96 g/day for R and S groups, respectively).The cold carcass weight averaged 14.4 kg and was not affected by feeding system (FS) (P>0.05). Dressing percentage and commercial dressing percentage were higher for the R group (P=0.05). FS had also an effect on the fattening state. In fact, the lambs in the R group had lower perirenal fat weight than that of the S group (208.15 *vs.* 369.01 g; P<0.01). Whereas, the subcutaneous fat thickness was similar between groups. In conclusion, the results show that feeding sheep on saline rangeland with a moderate supply of concentrate allows similar growth with less fatty carcass and a lower feed cost than those fattened indoor.

Keywords. Lamb – Rangeland – Halophytes – Grass pea – Growth – Carcass quality.

Halophytes et gesse commune comme ressource fourragère pour l'élevage d'agneaux en zone saline : Cas de l'archipel de Kerkennah

Résumé. *Les sols salins méditerranéens peuvent constituer une source précieuse d'éléments nutritifs pour le bétail. Dans l'archipel tunisien Kerkennah, caractérisé par une forte salinité du sol, la végétation halophyte pourrait remplacer partiellement le fourrage. En outre, certaines légumineuses autochtones, telles que Lathyrus sativus, pourrait être utilisée comme source de protéines au lieu du tourteau de soja. Dans ce contexte, nous avons étudié les effets de l'engraissement des agnelles sur un parcours riche en halophytes sur les performances de croissance et la qualité de la carcasse. Quarante agnelles sevrées de race Queue Fine de l'Ouest âgées de 153±32 jours et ayant un poids vif moyen de 25,45±4,33 kg, ont été réparties en deux groupes homogènes (n=20). Le premier groupe a été élevé en bergerie avec de la paille à volonté (LB). Le deuxième a été élevé sur un parcours riche en plantes halophytes (LP) (Suaeda mollis, Salsola longifolia, Medicago littoralis, Gasoul nodiflorum) avec un chargement de 3,33 agnelles/ha. LP et LB ont reçu respectivement une moyenne de 300 et 500 g/j d'aliment concentré contenant 12% de la gesse commune. Après 3 mois, les agnelles ont été abattues à 33 kg. Le GMQ moyen était identique entre les deux groupes (P>0,05) (92 vs. 96 g/j, respectivement pour LP et LB). Le poids de la carcasse froide était en moyenne de 14,4 kg et n'était pas affecté par le mode de conduite (MC) (P>0,05). Les rendements vrai et commercial étaient plus élevés pour le groupe LP (P=0,05). Le MC a eu un effet sur l'état d'engraissement. Les agnelles du groupe LP avaient un poids du gras péri-rénal inférieur à celui du groupe LB (208,15 vs. 369,01 g; P<0,01). Cependant, l'épaisseur du* gras de couverture *était similaire entre les groupes. En conclusion, l'engraissement des ovins sur un parcours salin avec un apport modéré d'aliment concentré permet une croissance similaire et d'avoir une carcasse moins grasse et une charge alimentaire plus faible que l'engraissement en bergerie.*

Mots-clés. *Agneaux– parcours – Halophytes – Gesse commune – Croissance – Qualité carcasse.*

I – Introduction

In the Mediterranean basin,the lamb's fattening ration is generally based on hay or straw with supplementation of concentrate, or on natural resources like rangelands.Several studies have shown that lamb reared on pasture could be a simple feeding strategy to naturally manipulate dietetic characteristics of sheep products. So, Jiménez *et al*. (2019) reported that finishing lambs on high-quality pasture can produce satisfactory growth rates without compromising characteristics of the carcass. Furthermore, Atti *et al*. (2015) found that carcass of lamb grazing grasslands, being leaner, will be demanded by consumers and recommended by nutritionists.

Pastoral resources depended mainly on weather conditions.Climate change, drought and salinity are among the dominant environmental problems in Tunisia that caused major challenges like the extension of the sabkha, with a progression of the adapted halophytic plants. Masters *et al*. (2007) suggested that many of these salt-tolerant forages are also capable of being converted into various livestock products. Ben Salem *et al*. (2004) also reported that halophytes could be alternative feeds to replace common roughages, especially for sustaining grazing livestock when common feeds are scarce. Therefore, some of these plants are palatable and can be well valued and provide a valuable source of nutrients for lambs. Nevertheless, fattening lambs on saline pasture is not sufficient to meet their needs, so supplementation with concentrate is necessary. In Tunisian conditions, soybean meal is the most used and expensive source of nitrogen in the concentrate. In a context of sustainability, it would be more interesting to value locally produced legumes such as grass pea (*Lathyrus sativus*).

The aim of this work was to characterize growth performances and carcass quality of female Queue Fine de l'Ouest lambs reared on natural saline pasture and to compare them to indoor lambs. All lambs were supplemented with concentrate containing grass pea.

II – Materials and methods

The trial was conducted in a farm of Kerkennah archipelago located in the governorate of Sfax,(arid region of Tunisia with an average annual rainfall of 246 mm), during spring season. Forty female weaned Queue Fine de l'Ouest lambs aged 153±32 days and with an initial body weight of 25.45±4.33 kg were divided into two homogeneous groups (n = 20) according to body weight and age. The first groups were housed indoor and received oat straw *ad libitum* (S). The second was reared on 6 ha of natural rangeland rich in halophytes of a coverage rate of 66.1 % for 6h daily (R). To satisfy nutrient needs, besides to the basal diet each group received the same concentrate (15% maize, 30% barley, 15% wheat bran, 9% soybean meal, 12% grass pea, 15% alfalfa plug and 4% CMV) with 300 and 500 g/head/day respectively for lambs reared on rangeland and those fed indoor. The animals were individually weighed before receiving the meal of the morning, at the beginning of the trial and every 21 days to calculate the average daily gain (ADG).

The floristic inventory was taken during April and May. The natural rangeland was composed of halophytic fodder shrubs and herbaceous species. The most frequent fodder shrubs were halophytes (61.53%):*Suaeda mollis* (30.84 %), *Salsola longifolia* (15.55%), *Reaumuria vermiculata* (12.23%), *Atriplex lindleyi* (1.14%), *Zygophyllum album* (1.10%) and *Arthrocnemum macrostachyum* (0.67%). For the herb species, rangeland was composed mainly of *Medicago littoralis* (22.79%), *Cynodon dactylon* (14.22%), *Gasoul nodiflorum* (3.16%), *Trigonella maritime* (2.42%) and *Erodium laciniatum* (1.34%).

At the end of the fattening period, lambs reached approximately an average final bodyweight (BW) of 33 kg. They were weighed before slaughtering on the farm. Then, they were transported to a commercial slaughterhouse, where they were re-weighed just before slaughtering (slaughter weight: SW). Lambs were slaughtered according to the Muslim practice and under veterinarian control. Also, the hot carcasses were weighed one hour after slaughter (hot carcass weight (HCW)), chilled at 4°C for 24h and re-weighed (cold carcass weight: CCW).

Dressing percentage (DP = HCW/(SW– digestive tract content: DTC) × 100) and Commercial dressing percentage (CDP = CCW/SW × 100) were calculated.

The carcass fatness was evaluated by the measurement of kidney fat weight and subcutaneous fat thickness. Kidney fat was removed and weighed. Subcutaneous fat thickness was measured using an Electronic Digital Calibrator after an incision between the 10^{th} and the 11^{th} ribs and about 4 cm to the right of the spinal column (Fisher and De Boer, 1994).

Data on the effects of diet on the various parameters (lamb growth and carcass quality) were treated with the GLM procedure (general linear model) using statistical analysis software (STATISTICA, version 5.5, USA). The model included one main factor: feeding system (saline pasture *vs*. indoor). Differences among means were considered to be significant when $P \leq 0.05$.

III – Results and discussion

The feeding system did not affect (P>0.05) the ADG, final body weight, slaughter weight, hot and cold carcass weights (Table 1). Results of growth performances were similar, despite that concentrate supplementation was higher for the S group. As a result, saline pasture is more balanced in terms of energy and nitrogen compared to the straw. In addition, dressing percentage and commercial dressing percentage were higher for the R group. These results confirm the findings of other previous studies that reported a better efficiency of grazing system with low concentrate supply (Smeti *et al.,* 2014; Atti *et al*., 2015).

Table 1. Effect of feeding system on growth and slaughter performances of female Queue Fine de l'Ouest lambs

	Feeding system		SEM	P-value
	Saline pasture	Indoor		
Weaning age (d)	152.10	154.55	5.079	0.813
Weaning weight(kg)	25.60	25.30	0.684	0.829
Final weight (kg)	32.90	32.95	0.749	0.974
Slaughter weight (kg)	30.98	31.83	0.550	0.463
Average daily gain (g)	92	96	3.945	0.859
Hot carcass weight (kg)	14.93	14.67	0.295	0.673
Cold carcass weight (kg)	14.53	14.36	0.298	0.781
Dressing percentage (%)	52.72	50.75	0.521	0.054
Commercial dressing percentage (%)	46.87	45.11	0.440	0.039

SEM: Standard error of mean; P: Probability.

Table 2. Effect of feeding system on carcass fatness of female Queue Fine de l'Ouest lambs

	Feeding system		SEM	P-value
	Saline pasture	Indoor		
Kidney fat weight (g)	208.15	369.01	30.144	0.003
Subcutaneous fat thickness (mm)	2.45	2.74	0.356	0.698

SEM: Standard error of mean; P: Probability.

Lambs in the R group had lower perirenal fat weight than that of the S group (208.15 *vs*. 369.01 g; P<0.05). Arieli *et al*. (1989) reported that the consumption of a high-salt diet requires higher energy requirements to process the high salt load, which would decrease the availability of energy for lipogenesis and reduce fat deposition. Nevertheless, the subcutaneous fat thickness was sim-

ilar between groups (P>0.05). This result is different from that reported by Majdoub-Mathlouthi *et al*. (2015), Hamdi *et al*. (2016) and Hajji *et al*. (2019). In fact, they explain the lower carcass fat of lamb grazing by the greater energy expenditure for physical activity.

IV – Conclusions

During the favorable season, grazing saline pasture, with a moderate concentrate supplementation offers the same lamb's growth and less fatty carcass than the indoor group fed on oat straw and higher amount of concentrate. Therefore, this management system could be recommended to alleviate the feeding cost and, consequently to increase farmer's income with the potential to improve the sustainability of sheep production in marginal areas.

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Feed efficiency in Alpine and Saanen lactating goats consuming a barn-dried hay obtained in a sustainable goat farming system (Patuchev)

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Abstract. In France, the aim of sustainable goat farming systems is to use more forages as a tool to increase feed self-sufficiency and to produce cheeses of high value. Thus, it is worthwhile to check the factors of variation of feed efficiency in dairy goats fed barn-dried hay produced in a system including pastures. Twenty-two mid-lactating dairy goats (11 Alpine and 11 Saanen) received *ad libitum* barn-dried hay obtained from fields at Inra Lusignan and a concentrate separately with a forage/concentrate ratio 55/45. Dry matter intake (DMI) expressed on a body-weight basis was higher for Alpine than for Saanen. Organic matter digestibility was not influenced by level of intake and was mainly function of indigestible cell wall. Fat and protein corrected milk yield (FPCMY) was directly proportional to digestible organic matter intake (DOMI). Feed efficiency (1.38 ± 0.137) or ratio of FPCMY/DMI is the product of the digestive efficiency (DOMI/DMI) by the metabolic efficiency (FPCMY/DOMI). It was mainly correlated to metabolic efficiency (r = 0.97), but not to digestive efficiency, probably due to its low range of relative variation. It increased with the level of milk production and tended to be higher for Saanen than for Alpine goats when milk production was used as a covariate. Moreover, the ratio "N output in milk/N intake" with the tested diet was directly proportional to feed and metabolic efficiencies. Thus, in our context, high producing animals have a better feed efficiency.

Keywords. Feed efficiency – Barn-dried hay – Dairy goat.

Etude de l'efficacité alimentaire du foin ventilé obtenu dans un système durable (Patuchev) pour des chèvres laitières

Résumé. *En France, l'objectif des systèmes de production durables est de maximiser l'utilisation des fourrages comme moyen d'améliorer l'autonomie alimentaire et de produire des fromages à haute valeur ajoutée. Il est donc important de quantifier les facteurs de variation de l'efficacité alimentaire du foin ventilé produit dans un système incluant du pâturage et distribué à des chèvres laitières. Vingt-deux chèvres (11 Alpine et 11 Saanen) ont reçu, en quantité ad libitum, du foin ventilé cultivé à l'Inra de Lusignan et séparément de l'aliment concentré avec un ratio fourrage/concentré de 55/45. Les chèvres de race Alpine ont ingéré plus de matière sèche (MSI rapportée au poids vif) que les Saanen. Le niveau d'ingestion n'a pas influencé la digestibilité de la matière organique qui était essentiellement fonction de la teneur en paroi indigestible. La production laitière standard (PLS, corrigée par les taux butyreux et protéique) a été directement proportionnelle à la quantité de matière organique digestible ingérée (MODI). L'efficacité alimentaire (1,38 ± 0,137) ou rapport PLS/MSI est égal au produit de l'efficacité digestive (MODI/MSI) par l'efficacité métabolique (PLS/MODI). Elle est principalement liée à l'efficacité métabolique (r = 0,97), mais pas à l'efficacité digestive, probablement due à la faible variation relative de cette dernière. L'efficacité alimentaire a augmenté avec le niveau de production laitière et a été numériquement plus élevée pour les Saanen que pour les Alpine quand la production laitière est prise en compte. De plus, le ratio « N excrété dans le lait/ N ingéré » était directement proportionnel aux efficacités alimentaire et métabolique. Ainsi, dans le contexte présent, les animaux à haut niveau de production ont une meilleure efficacité alimentaire.*

Mots-clés. *Efficacité alimentaire – Foin ventilé – Chèvre laitière.*

I – Introduction

Feeding barn-dried hay to dairy goats is one option to improve sustainability of goat farming system as a tool to increase self-sufficiency and to produce cheeses of high sale value, especially in France that is the leading goat cheese producer in Europe (ANICAP (Association Nationale Interprofessionnelle Caprine), 2017). The aim of this work is to check the factors of variation of feed efficiency in dairy goats fed a diet containing barn-dried hay from grazed and mown grasslands and concentrate to fulfil their requirements. Goats were from the two predominant breeds in France: Alpine and Saanen (Idele (Institut de l'Elevage), 2018).

II – Material and methods

The present study was handled in accordance with the French legislation on animal experimentation and European Convention for the Protection of Vertebrates used for Experimental and other Scientific Purposes (European Directive 86/609). The protocol was approved by the ethical local committee (Comité d'Ethique en Expérimentation Animale, COMETHEA 45) and was registered as 15-79.

Twenty-two dairy goats were allotted in two groups according to their breed: 11 Alpine (A) and 11 Saanen (S). Six goats were in second lactation (3A and 3S), six on third lactation (2A and 4S) and another six, in fourth lactation (3A and 3S) and the remaining four in fifth lactation (3A and 1S). They were in mid-lactation at the beginning of the trial (81 ± 3.1 Days in Milk) and milked twice a day around 7 am and 3 pm. They were fed *ad libitum* barn-dried hay (at least 15 % refusals) twice a day: two thirds of hay were delivered after the afternoon milking and one third after the morning milking according to the intervals between milkings. This hay was produced from multi-species grasslands of the experimental platform Patuchev (UE FERLus-Inra Lusignan). Grasslands were composed of fescue, brome, Italian rye-grass, alfalfa, white and red clovers. Goats received separately a commercial concentrate (Fluvialac®) in 4 meals (one third after each milking and one sixth at the end of the morning (around 11 am) and at the end of the afternoon (around 5 pm). The quantity of concentrate was adapted to each goat to obtain a forage/concentrate ratio of 55/45 on a dry matter basis.

Goats were housed in individual crates during the 9-weeks trial. Six Alpine and six Saanen were moved to one of the 12 digestibility crates (Giger and Hervieu, 1980) after five weeks of adaptation and the ten remaining (5A and 5S) after seven weeks because only twelve crates were available. Digestibility measurements were performed during a five days period after one week of adaptation to the digestibility crates. Body weight was measured before the period in digestibility crates around 2 p.m.

The dry matter (DM) and ash contents of feeds, refusals and faeces were determined according to ISO methods (ISO, 1978; ISO, 1983). Total N was determined by the Dumas technique (Sweeney and Rexroad, 1987). The NDF (or cell wall) content was estimated by the method of Van Soest and Wine (1967) modified by Giger *et al.* (1987) with the use of a heat stable α-amylase but without sodium sulphite and decalin. Fat and protein contents of milk were analysed by infrared spectrophotometry (labo Uriane, La Capelle, Aisne, France). Milk yield was corrected for fat and protein contents (Sauvant and Giger Reverdin, 2018).

Breed effect was tested by an ANOVA procedure on the mean values per goat.

III – Results and discussion

1. Intake and milk yield

Dry matter intake (DMI) during the digestibility trial period was higher for Alpine goats than for Saanen goats expressed in kg/d or in g/kg body weight/d (Table 1). N intake per day was also higher for Alpine compared to Saanen, such as raw milk yield. Fat and Protein corrected milk yield (FPCMY) only tended to be higher for Alpine goats due to a lower numerical value for fat content compared to Saanen.

Table 1. Breed effect on body weight, intake, milk yield and composition (n= 11 goats per breed)

	Alpine	Saanen	P value
Intake and body weight			
Body weight (kg)	62.6 (± 6.36)	65.7 (± 4.66)	0.20
DMI (kg/d)	3.31 (± 0.233)	3.02 (± 0.222)	0.01
DMI (g/kg of BW per day)	53.2 (± 4.74)	46.1 (± 4.19)	0.001
N intake (g per day)	93.9 (± 8.00)	84.7 (± 7.00)	0.009
Milk yield and composition			
Raw milk yield (kg/d)	4.42 (± 0.352)	3.96 (± 0.514)	0.03
Fat	36.6 (± 3.11)	38.1 (± 6.15)	0.47
Protein	32.3 (± 3.09)	31.7 (± 2.09)	0.66
Fat and Protein corrected milk yield (kg/d)	4.56 (± 0.358)	4.16 (± 0.636)	0.09

2. Digestibility and feed efficiency

Organic matter, cell wall (NDF) and crude protein digestibilities were similar for the two breeds (Table 2). Organic matter digestibility of the diet was not influenced by the level of intake, but it was mainly function of the indigestible part of the cell wall measured for each goat ($r = 0.88$, $n = 22$, RSD = 0.785, $P < 0.01$) in agreement with the Inra 2018 system (Baumont *et al.*, 2018). Corrected milk yield was directly proportional to the digestible organic matter intake (DOMI):

Corrected milk yield = 2.24 (± 0.047) (DOMI kg/d) ($r= 0.61$, $n = 22$, RSD =0.440 kg/d, $P < 0.01$)

Feed efficiency was calculated as the ratio of FPCMY on DMI expressed in kg/d (Arndt *et al.*, 2015). Thus, it is also the product of the ratio of DOMI/DMI (digestive efficiency) by the ratio FPCMY/DOMI (metabolic efficiency). There is no breed effect for all the efficiencies (Table 2).

Feed efficiency was mainly correlated to metabolic efficiency:

Feed efficiency = 0.614 (± 0.0033) Metabolic efficiency ($r = 0.97$, $n = 22$, RSD = 0.0348, $P <0,01$)

Feed efficiency was not correlated with digestive efficiency ($r = 0.12$, $n = 22$, $P = 0.58$). This was probably due to the low range of relative variation of digestive efficiency (2.55 %) compared to metabolic (9.89 %) or feed efficiency ‘9.93 %). Feed efficiency increased linearly with the level of FPCMY and was numerically higher for Saanen than for Alpine goats when FPCMY was used as a covariate ($P=0.052$). It must also be stressed that the ratio “N output in milk/N intake” was directly proportional to feed efficiency ($r = 0.75$, $n = 22$, $P < 0.01$) and to metabolic efficiency ($r = 0.66$, $n = 22$, $P < 0.01$) and not correlated to digestive efficiency ($r = 0.33$, $n = 22$, $P = 0.14$).

Table 2. Breed effect on digestibility and feed efficiency (n= 11 goats per breed)

	Alpine	Saanen	P value
Digestibility			
Organic matter (%)	67.7 (± 1.49)	67.1 (± 1.66)	0.36
Cellwall or NDF (%)	54.1 (± 5.50)	52.4 (± 4.17)	0.42
Crude protein (%)	68.7 (± 1.69)	67.5 (± 2.48)	0.19
Efficiency			
Feed efficiency	1.38 (± 0.098)	1.38 (± 0.172)	0.98
Digestive efficiency	0.617 (± 0.0160)	0.612 (± 0.0158)	0.48
Metabolic efficiency	2.24 (± 0.169)	2.25 (± 0.274)	0.89

IV – Conclusion

High producing animals have better feed efficiency than low producing ones with barn-dried hay obtained in a sustainable goat farming system, and the difference between breeds in intake has no influence on feeding efficiency.

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Characterization of goat neonatal mortality in northern Morocco and impact of colostrum supplementation

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Abstract. This present work aims (1) to characterize neonatal mortality of young goats in northern Morocco in relation with passive transfer of immunity via colostrum, and (2) to test a complementation strategy with commercial colostrum in order to increase kid's immunoglobulin concentration levels for a better protection against infections. This study was performed between November 2016 and May 2018 in northern Morocco. (1) A group of 1236 newborn kids of Beni Arouss, Northern breed and Northern cross breeds where monitored every 15 to 20 days. Regular weight assessment and blood samples on kids aged between 0 and 14 days were performed. (2) For complementation assay (2017-2018), 65 Beni Arouss goat kids were chosen to receive commercial colostrum. To maintain the mother-young bond, kids were allowed to suckle their mother's immediately after birth. Then, they received one meal (50 between 150 ml of bottled commercial colostrum) for 3 consecutive days, in addition to maternal milk. Animals of this group were compared to non supplemented Beni Arouss kids living in the same farming conditions (n=81). Results showed a mortality rate in goat kids of northern Morocco of 16%, which was significantly lower in Beni Arouss (8%; p<0.01) and mountainous pastures (11%; p<0.05). Median immunoglobulin levels were significantly lower in Beni Arouss kids (8.20 g/L; p<0.05). Supplementation with commercial colostrum of Beni Arouss goat kids in addition to their mother's milk did not reduce mortality rate. Mortality occurring between 0-3 days was however decreased (10% versus 31% in non-complemented kids) and immunoglobulin levels were significantly increased (18.95 g/L versus 8.32 g/L in non-complemented kids; p<0.05).

Keywords. Neonatal mortality – Goat – Northern Morocco – Immunoglobulin.

Caractérisation de la mortalité néonatale caprine dans le nord du Maroc et impact de la supplémentation en colostrum

Résumé. *Le présent travail vise (1) à caractériser la mortalité néonatale des chevreaux dans le nord du Maroc en relation avec le transfert passif de l'immunité via le colostrum, et (2) à tester une stratégie de complémentation avec du colostrum commercial afin d'augmenter les niveaux de concentration en immunoglobuline des chevreaux pour une meilleure protection contre les infections. Cette étude a été réalisée entre novembre 2016 et mai 2018 dans le nord du Maroc. (1) Un groupe de 1236 nouveau-nés de Beni Arouss, races du Nord et races du Nord croisées ont été suivis tous les 15 à 20 jours. Une évaluation du poids et des prélèvements de sang sur les chevreaux âgés de 0 à 14 jours ont été effectués régulièrement. (2) Pour l'analyse de la complémentation (2017-2018), 65 chevreaux Beni Arouss ont été choisies pour recevoir du colostrum commercial. Pour maintenir le lien mère-jeune, les chevreaux étaient autorisés à téter immédiatement après la naissance. Ensuite, ils ont reçu un repas (50 entre 150 ml de colostrum commercial en bouteille) pendant 3 jours consécutifs, en plus du lait maternel. Les animaux de ce groupe ont été comparés à des chevreaux Beni Arouss non complémentés vivant dans les mêmes conditions d'élevage (n = 81). Les résultats ont montré un taux de mortalité de 16% chez les chevreaux du nord du Maroc. La mortalité néonatal était nettement inférieur à Beni Arouss (8%; p <0,01) et dans les pâturages montagneux (11%; p <0,05). Les taux médians d'immunoglobuline étaient significativement plus faibles chez les chevreaux de la race Beni arouss (8,20 g / L; p <0,05). La supplémentation en colostrum commercial des chevreaux Beni Arouss en plus du lait de leur mère n'a pas réduit le taux de mortalité. La mortalité survenant entre 0 et 3 jours a cependant diminué (10% contre 31% chez les chevreaux non complémentés) et les taux d'immunoglobuline ont été significativement augmentés (18,95 g / L contre 8,32 g / L chez les chevreaux non complémentés; p < 0,05).*

Mots clés. *Mortalité néonatale – Chèvre – Nord du Maroc – Immunoglobuline.*

I – Introduction

High levels of mortality in young goats are recognized as a major constraint on goat production wherever goats are raised. In extensive management systems, kid losses have been reported in the range from 10 to 60% (Grafton, 1993). In northern Morocco, high mortality rates of young goats range from 16% to 34% (Chentouf *et al*., 2014).These deaths occur most frequently in the first few days of life. Numerous factors contribute to this early mortality, including low birth weight, short gestation period, large litter size, poor mothering, and hypothermia, as well as other environmental and weather conditions at the time of kidding. In addition, the failure to suckle adequate colostrum at birth contributes significantly to the preponderance of early kid deaths, most likely through the mechanism of failure of passive transfer of humoral immunity (Grafton, 1993).

This present work aims to characterize mortality of young goats in northern Morocco in relation with passive transfer of immunity via colostrum, and test a complementation strategy with commercial colostrum in order to increase kid's immunoglobulin concentration levels for a better protection against infections.

II – Materials and methods

1. Study design

In order to compare a range of appropriate situations throughout two seasons of follow-up: 2016-2017 (n=16) and 2017-2018 (n=9) in northern Morocco, we selected farms in rural areas that had smallholder farmers, clear access to farms during wet season.

2. Animals' enrolment

Only females that gave birth during the study period were eligible (n=1106). Kidding season begun in December and ended in March of each year. All along this season, farms' visits were scheduled every 15 to 20 days. During visits, first time checked newborns (n=1236) were given numbered neck tags that switched to numbered ear tags 30 days later and were weighed. Blood sampling was performed if kid's age ranged between 0 and 14 days at first investigation (n= 80).

For the supplementation assay that was conducted in 2017-2018, a total of 65 Beni Arouss goat kids were chosen to receive commercial colostrum Globigen® (Alliance pastorale, France).

To maintain the mother-young bond, kids were allowed to suckle their mother's immediately after birth. Then, they received one meal (50 between 150 ml of bottled commercial colostrums) for 3 consecutive days, in addition to maternal milk. Animals of this group were compared to 81 non supplemented Beni Arouss kids living in the same farming conditions (n=81).

3. Sampling and determination of IgG concentrations

To estimate the efficiency of passive immunity transfer from goats to their newborns, a single jugular blood sample was taken from newborn kids aged less than 14 days. Supplemented group kids were sampled twice (at 48h and 7 days after birth). Blood samples were centrifuged and serum stored at –4°C. Blood serum was assayed to determine IgG concentration by radial immunodiffusion technique using RID Sheep and Goat IgG test (IDBiotech,France). Detection limit was 5 ! g/ml. The inter-assay coefficient of variation (CV) was 7%; intra-assay CV was 5%.

4. Statistical analysis

Data of IgG concentrations were analyzed as a linear mixed model after log10 transformation. The model was fitted in the R statistical environment using the lme4 package. In addition, boxplots of non transformed data were plotted to check for any factors' effect. Mortality data were analyzed as a generalized linear model (GLM).

III – Results and discussion

In northern Morocco, the most common breeds are: the Northern Cross population which is the result of a cross between local breed and an imported breed; the Northern Local population; and Beni Arouss goat recently recognized as a breed by the Ministry of Agriculture (Chentouf *et al*., 2014). Farmers use either forest resources from lowlands or mountains for goats' pasture.

The overall goat mortality rate in our study was 16%. Our results were similar to those in extensive goat farms of northern Morocco when goat kids mortality rate was estimated at 16.2% between 2003 and 2004 (Chentouf, *et al*., 2006). Mortality rate in kids born in lowlands (23%) was higher compared to that of kids born in the mountains (11%) ($p<0.05$). The difference in death rates was also significant ($p=0.01$) between the three breeds of the region: the Northern Cross population (8%), the Northern Local population (17%) and Beni Arouss goat (8%).

Immunoglobulin concentration level was highly affected by breeds ($p<0.05$). The median concentrations of each breed were: 10.22 g/l for the Northern Cross population, 10.76 g/l for the Northern local population (17%) and 8.20 g/l for Beni Arouss goat (Fig. 1). Our results were similar to the study confirming that kids with immunoglobulin levels <8 g/l showed lower survival rates than those with higher concentrations (Mellado *et al*., 1998).

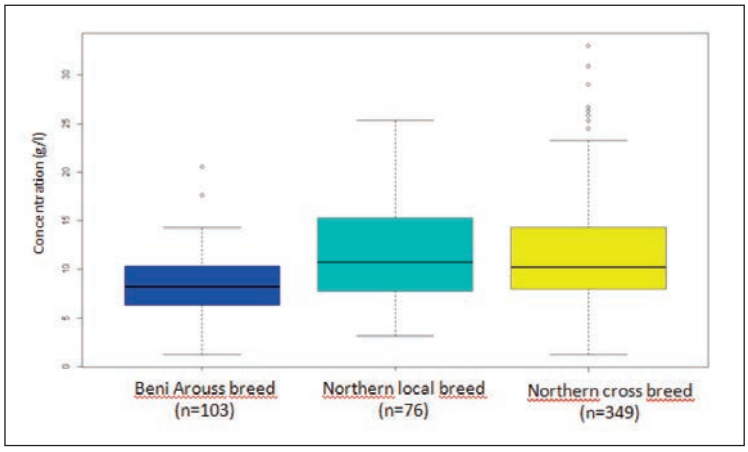

Fig. 1. Effect of breed on serum IgG concentration (g/L) in goat kids after colostrum intake.

Regarding colostrum supplementation, mortality rate equalled 15% in supplemented group and 16% in non supplemented goats (Table 1). Mellado and colleagues (1998) found similar results under extensive management conditions in the arid zones of Mexico during spring: this study showed that reduced immunoglobulin concentration in kids was not associated with lower survival rates.

Results showed a highly significant effect of supplementation using commercial colostrum on immunoglobulin levels compared to non supplemented group ($p<0.05$). Values for dead kids were at 20.66 g/L at 48 h and 10.39 g/L at 7 days in supplemented group and 8.20 g/L at 48 h and 7.62 g/L at 7 days in non supplemented group, respectively. For alive kids the levels were 18.95 g/L at 48h and 13.04 at 7 days versus 8.32 g/L at 48h and 8.20 at 7 days (Table 1).

There was no significant differences between dead and alive kids' immunoglobulin levels in both groups. Supplemented dead kids showed 20.66 g/L at 48h and 10.39 g/L at 7 versus 18.95 g/L at 48h and 13.04 g/L at 7 days for supplemented alive kids. Values in non supplemented kids group were at: 8.20 g/L at 48h and 7.62 g/L at 7 days for dead kids versus 8.32 g/L at 48h and 8.20 g/L at 7 days for alive kids (Table 1). Mortality occurring between 0-3 days was however decreased in complemented kids 10% versus 31% in non-complemented kids.

Table 1. Median IgG concentrations (g/L) and death rates in supplemented and not supplemented goat kids

	Supplemented kids				Not supplemented kids			
	Dead occurring during follow up		Alive throughout follow up		Dead occurring during follow up		Alive throughout follow up	
Time	48h	7 days	48h	7 days	48h	7 days	48h	7 days
Number	10	8	55	55	7	6	42	25
Median (g/L)	20.66a	10.39a	18.95a	13.04a	8.20b	7.62b	8.32b	8.20b
Max.	28.29	20.66	33.01	25.10	12.05	13.06	17.63	14.30
Min.	13.39	6.73	8.68	5.89	4.29	2.09	1.74	1.74
Mortality rate			15%				16%	

Data shown in the row with different letters (a and b) has a significant difference ($p<0.05$).

IV – Conclusion

In our study, mortality rate in goat kids of northern Morocco was of 16% between 2016 and 2018 and was highly affected by goats' breed and type of pasture, with Beni Arouss population and mountainous pastures showing the lowest mortality rate. Immunoglobulin levels after colostrum absorption were lowest in Beni Arouss goat kids. Supplementation with commercial colostrum of Beni Arouss goat kids in addition to their mothers' milk increased significantly post-colostrum serum immunoglobulin levels but did not reduce mortality.

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Nutritional and production aspects of partially or totally replacing berseem hay by cassava in ewes feeding

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Abstract. Berseem (*Trifolium Alexandrinum*) is the traditional winter forage in the Mediterranean-Middle East regions. In Egypt, berseem has achieved the distinction of being a base for livestock production due to its high nutritive value and easy cultivation. However, the absence of berseem during summer season cause a limiting factor for livestock production. So the objectives of this study were to evaluate the nutritional and production aspects of partially or totally replacement of berseem hay by cassava in ewes diets on ruminal fermentation, milk production and lamb performance. Forty late pregnant Barki ewes were assigned to four experimental diets (n = 10 each): i.e. control [50% berseem hay and 50% concentrate mix] or [33, 66 and 100% replacement of berseem hay by leaves and thin twigs of cassava hay] plus 50% concentrate mix for a period of 4 weeks before the expected lambing date until 8 weeks of lactation. 100% replacement of cassava resulted in increasing ($p < 0.05$) individual (acetate and propionate) and total volatile fatty acid concentration compared with other treatments. Ruminal NH_3-N concentrations and total protozoa were decreased ($p < 0.05$) with 66 and 100% cassava replacement compared with control. Milk yield was improved ($p < 0.05$) by total replacing of cassava in addition milk fat, protein and lactose percentages were increased ($p < 0.05$) by 100% of cassava rather than other treatments. Lamb growth rate and weaning weight were enhanced ($p = 0.022$) by 100% cassava compared with other diets. Thus, using 100% replacement of berseem by cassava provides a promising source of forages for sheep with positive impacts on fermentation and ewes productivity.

Keywords. Cassava – Rumen fermentation – Milk yield and composition – Lamb growth rate.

Aspects nutritionnels et de production liés au remplacement partiel ou total du foin de berseem par du manioc dans l'alimentation des brebis

Résumé. *Le berseem (*Trifolium alexandrinum*) est le fourrage traditionnel d'hiver des régions de la Méditerranée et du Moyen-Orient. En Égypte, le berseem s'est distingué comme étant une base pour la production animale en raison de sa haute valeur nutritive et de sa facilité de culture. Cependant, l'absence du bersem pendant la saison d'été est un facteur limitant pour la production animale. Les objectifs de cette étude étaient donc d'évaluer les aspects nutritionnels et de production du remplacement partiel ou total du foin de berseem par du manioc dans l'alimentation des brebis sur la fermentation ruminale, la production de lait et les performances de l'agneau. Quarante brebis Barki en fin de gestation ont été affectés à quatre régimes expérimentaux (n = 10 chacun): c.-à-d. Témoin [50% de foin de berseem et 50% de concentré] ou [33, 66 et 100% de remplacement du foin de berseem par des feuilles et de minces brindilles de manioc foin] plus 50% de concentré pendant une période de 4 semaines avant la date prévue d'agnelage jusqu'à 8 semaines de lactation. Le remplacement à 100% du manioc a entraîné une augmentation ($p < 0,05$) de la concentration individuelle (acétate et propionate) et totale d'acides gras volatils par rapport aux autres traitements. Les concentrations dans le rumen de NH_3-N et les protozoaires totaux ont diminué ($p < 0,05$) avec un remplacement de manioc de 66 et 100% par rapport au témoin. Le rendement laitier a été amélioré ($p < 0,05$) par le remplacement total du manioc. De plus, les pourcentages de matière grasse, de protéines et de lactose ont été augmentés ($p < 0,05$) de 100% de manioc plutôt que d'autres traitements. Le taux de croissance et le poids au sevrage ont été aug-*

mentés (p = 0,022) de 100% de manioc par rapport aux autres régimes. Ainsi, le remplacement à 100% de berseem par du manioc constitue une source prometteuse de fourrages pour les ovins, avec des effets positifs sur la fermentation et la productivité des brebis.

Mots-clés. *Manioc – Fermentation dans le rumen – Rendement et composition en lait – Taux de croissance de l'agneau.*

I – Introduction

In the developing countries there is a serious need of searching for alternative feed resources because of the limited area for agriculture and the competition between animals and humans for some crops. In addition, these alternative feeds should be friendly to the environment and have good impacts on animal production and quality, which will reflect on consumer's acceptance. Vast areas of Mediterranean-Middle East are characterized by high salinity arid and semi-arid zones, where halophyte forages are the most common plant species naturally grown (Ahmed *et al*., 2015). Many of these plant species yield high volumes of green biomass and contain substantial amounts of digestible protein (Morsy *et al*., 2018). In addition, they contain bioactive phytofactors, such as tannins and cyanogenic glycosides which have shown to possess antimicrobial, antimethanogenic, antioxidant, and immunomodulatory properties (Soltan *et al*., 2012, 2017; Morsy *et al*., 2018). Thus, we suggested that feeding ewes on these forages may affect animal performance. The objectives of this study were to evaluate cassava (*Manihot esculenta*) dried leaves and thin twigs to partially or totally replace berseem hay in the diet of late pregnant Barki ewes, on nutritional and production aspects in addition to the performance of their offspring.

II – Materials and methods

1. Animals

Forty late pregnant Barki ewes similar in total account of parity, milk yield to previous lactation and body weight (42.5 ± 1.25 kg SE) were randomly assigned to one of 4 dietary treatments for a period of 4 weeks before the expected lambing date until 8 weeks of lactation. The ewes were grouped (10 ewes/group) for treatments into: group 1 (control): received a diet consisting of berseem hay (50%), corn (27%), cotton seed meal (24%), wheat bran (10.5%), molasses (5.5%), NaCl (0.5%), NaHCO3 (2%) and vitamin mix (0.5%) on DM basis; and groups 2, 3 and 4: receiving the same diets as the control, but after partial or total replacement of berseem hay with 33, 66 and 100% cassava hay, respectively. These diets were formulated according to NRC requirements (NRC, 2007). Ewes were kept in semi-open sheds and fed the corresponding diets as a total mixed ration at 4% of BW twice daily while had free access to fresh water. After birth, all lambs were allowed to suckle colostrum for about two hours. Lamb birth weight was recorded 24 h after birth and weaning weight at the eighth week of lamb age. Lambs were reared with their dams with free access to water but had no reach to dams feed.

2. Sampling and analyses

Representative samples of all diets were analyzed according to AOAC (1995) for dry matter, organic matter, and crude protein (CP). Contents of neutral detergent fiber, acid detergent fiber and lignin were measured following Van Soest *et al*. (1991). Determinations of total phenols, condensed tannin (CT) and total tannin were according to Makkar (2003). Cyanide was measured colorimetrically following Orjiekwe *et al*. (2013). The ruminal fluid was collected biweekly from the begin of the experiment. Samples were collected via the stomach tube at 1.0, 3.0 and 6.0 h after feeding. The rumen fluid was separated from the feed particles through four layers of gauze and approximately 1 ml was taken for protozoa counts, while the rest was stored at –20°C for later analysis of NH_3-N and

VFA's. Milk samples and yield was recorded twice weekly, animals were milked at 07:00 and 16:00 h as described by Morsy *et al*., 2016. Milk samples were analyzed as described by Morsy *et al*. (2016) for fat, protein, lactose and total solids using infrared method (EKOMILK-M ultrasonic milk analyzer, EON Trading INC, Bulgaria, 2000). Lamb birth weight was recorded 24 h after birth and weaning weight at the eighth week of lamb age. Data were statistically analyzed according to a completely randomized design using GLM procedure of SAS software 2002 (Version 9.2).

III – Results and discussion

The effects of partially or totally replacing berseem hay by cassava in ewe's diets on ruminal fermentation parameters are shown in Table 1. The total (100%) replacement of berseem by cassava resulted in increasing ($p < 0.05$) individual (acetate and propionate) and total volatile fatty acids concentration compared with control treatments. Ruminal NH3-N concentration and total protozoa were decreased ($p < 0.02$) with 66 and 100% cassava replacement compared with control.The presence of plant bioactive phytofactors like tannins and / or cyanogenic glycosides present in cassava might have a positive effect on animal productivity by affecting the ruminal microbial ecosystem (Soltan *et al*.,2012 and 2017). Our results are in agreement with Oni *et al*. (2010) who concluded that inclusion of dried cassava leaves at 60% promotes good growth performance, nutrient digestibility, nitrogen utilization in West African dwarf goats and reduces feeding costs.

Table 1. Effect of partiality or totally replacement of berseem hay by cassava in ewe's diets on ruminal fermentation parameters

Parameters	Treatments				SEM	Probability
	Control	33%	66%	100%		
Total VFA (mM)	70.01^{b}	89.31^{ab}	89.01^{ab}	94.00^{a}	5.18	0.055
Acetate % of total	43.38^{b}	58.31^{a}	60.58^{a}	63.23^{a}	2.550	0.050
Propionate % of total	11.28^{b}	12.00^{ab}	10.26^{b}	15.68^{a}	1.140	0.051
Butarate % of total	15.74^{ab}	19.19^{a}	18.64^{a}	14.35^{ab}	0.900	0.031
NH_3-N (mg/100ml)	19.81^{a}	18.74^{a}	16.12^{b}	15.11^{b}	0.670	0.023
Protozoa (105/ml)	7.01^{c}	6.51^{b}	6.6^{b}	4.8^{b}	0.447	0.021

^{a,b,c} Means with different letters within the row are significant different P<0.05.

Table 2 presents the effect of cassava replacement on milk yield and composition of Barki ewes. Milk yield was improved ($p < 0.02$) by total replacing of berseem hay by cassava. In addition milk fat, protein and lactose percentages were increased significantly by the 100% cassava replacement compared to the other treatments. The enhancement of milk production by cassava inclusion could be attributed to the better fermentation and suitable condition in the rumen for better nutrient utilization, resulting in higher levels of individual and total VFAs witch then reflected on milk production.

Table 2. Effect of partiality or totally replacement of berseem hay by cassava in ewe's diets on milk yield and composition

Parameters	Treatments				SEM	Probability
	Control	33%	66%	100%		
Milk yield (kg)	1008^{b}	1143^{b}	1138^{ab}	1261^{a}	32.1	0.026
Fat %	6.60^{c}	7.07^{b}	7.12^{b}	7.79^{a}	0.084	0.001
Protein %	3.71^{a}	3.56^{b}	3.62^{ab}	3.66^{ab}	0.018	0.025
Lactose%	5.33^{b}	5.36^{b}	5.38^{b}	5.64^{a}	0.040	0.024
Total solids%	9.09	8.68	8.91	9.09	0.083	ns

^{a,b,c} Means with different letters within the row are significant different P<0.05.

Regarding lamb performance, cassava replacement resulted in increasing lamb growth rate and weaning weight as presented in Table 3.

Table 3. Effect of partiality or totally replacement of berseem hay by cassava in ewe's diets on ruminal fermentation parameters

Parameters	Treatments				SEM	Probability
	Control	33%	66%	100%		
Birth weight (kg)	3.20	3.53	3.22	3.22	0.185	ns
Weaning weight (kg)	12.40^{b}	14.00^{ab}	13.75^{ab}	15.00^{a}	0.823	0.030
Growth rate (g / day)	164^{b}	186^{ab}	187^{ab}	212^{a}	0.014	0.024

^{a,b} Means with different letters within the row are significant different P<0.05.

The increase of milk yield and enhancement of milk quality as presented previously could explain the superior weaning weight and growth rate of lambs produced from ewes fed on diets in which cassava replaced partiality or totally the berseem hay.

IV – Conclusions

Using 100% replacement of berseem by cassava provides a promising source of forages for sheep with positive impacts on fermentation and ewe's productivity.

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Garlic (*Allium sativum* L.) chemical composition, antioxidant and antimicrobial activities, and *in vitro* effect on digestion in sheep

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Abstract. An *in vitro* study also was conducted to evaluate the effect of garlic (*Allium Sativum* L.) powder (GaP) supplementation on rumen fermentation. Two successive 24 h-incubations were practiced. Growing doses of garlic powder were added to 500 mg of a diet composed (50% of rye-grass hay, 50% of concentrate on DM basis). pH, ammonia nitrogen (NH_3-N) and true organic matter degradability (TOMD) were measured and partitioning factor (PF) and microbial biomass (MBM) were estimated. Results showed that garlic powder was low in ash (3.5 % DM), relatively high in CP (16.6% DM) and very lowly lignified (ADL < 2.2 % DM). Colorimetric analysis revealed that total phenols, flavonoids and tannins contents were respectively 0.37 mg AG.eq, 0.11 mg EC and 30.2 mg EC /g DM. All aqueous extracts exhibited a high, concentration dependent, free radical-scavenging activity. It was found that all extracts exhibited antibacterial activity against Gram(–) (*Escherichia coli*) and Gram(+) bacteria (*Staphylococcus aureus* and *Bacillus subtilis*), but ethanol extract was proven to be more efficient against the Gram(–) bacteria. The *in vitro* trial results indicated that GaP (32 and 64 mg doses) increases significantly (P<0.001) gas production after 24 h. No effect on pH was observed. An increase (P<0.0001) in NH3-N concentration was recorded with 4 mg and 8 mg doses compared with control; whereas adding 32 and 64 mg resulted in a NH3-N concentration equivalent to control. Total VFA concentration noted with control (73.6 $mmolL^{-1}$) was lower (P<0.001), compared to that noted from adding GaP (averaged 99.28 $mmolL^{-1}$). The propionate (C3) increased with GaP, and the highest proportion was noted with the addition of 8 mg (*P* <0.001). The TOMD was similar for all the doses except for 64 mg GaP, where a slight but significant (*P* <0.001) increase was noted (77.7%). PF values were equivalent in all doses (averaged 3.2), while a significant (*P*<0.0001) increase (4.45) was noted with 64 mg. The same trend was observed in MBM (*P* <0.001). It was concluded that GaP present some advantages related to its antioxidant and antimicrobial actions and could be considered as a natural alternative to synthetic antioxidants. Also, it modified positively rumen fermentations. *In vivo* and performance and quality measurements are necessary to confirm the eventual positive benefits of garlic on ewes feeding.

Keywords. Garlic – Secondary compounds – Antioxidant – Antimicrobial activities – *In vitro* fermentation – Sheep.

L'ail (*Allium sativum *L.) dans la nutrition des ruminants: composition chimique, activités antioxydante et antimicrobienne et effet in vitro sur la digestion chez les ovins

Résumé. *Une étude* in vitro *a été menée pour évaluer l'effet de la supplémentation avec de la poudre d'ail (PA) sur la fermentation dans le rumen. Deux incubations successives de 24 h ont été pratiquées. Des doses croissantes de poudre d'ail ont été ajoutées à 500 mg d'un régime composé de 50% de foin de ray-grass et de 50% de concentré. Le pH, l'azote ammoniacal (NH3-N) et la dégradabilité réelle des matières organiques (TDMO) ont été mesurés, el le facteur de partition (PF) et la biomasse microbienne (MBM) ont été estimés. La PA était faible en cendres (3,5% MS), relativement élevée en MAT (16,6% MS) et très faiblement lignifiée (teneur en ADL <2,2% MS). L'analyse colorimétrique a révélé que les teneurs totales en phénols, en flavonoïdes et en tanins étaient respectivement de 0,37 mg d'AG.eq, 0,11 mg EC et 30,2 mg EC / g de MS. Tous les extraits aqueux présentaient une activité de piégeage des radicaux libres élevée. Les extraits présentaient une activité antibactérienne contre presque toutes les bactéries (Escherichia coli, Staphylococcus aureus et Bacillus subtilis) mais l'extrait d'éthanol était plus efficace contre les bactéries Gram(–). L'essai in vitro a indiqué que la PA (en doses de 32 et 64 mg) augmente (P <0,001) la production de gaz pour après 24 h. L'ail n'a eu aucun effet sur le pH. Une augmentation (P <0,0001) de la concentration en NH3-N a été enregistrée avec les*

doses 4 mg et 8 mg, alors que l'ajout de 32 et 64 mg a entraîné une concentration équivalente au contrôle (moyenne de 39,25 mg / 100 ml). L'ajout de PA a entraîné une augmentation équivalente des concentrations en AGVs totaux pour toutes les doses (moyenne de 99,28 mmolL^{-1}, par rapport aux 73.6 mmL^{-1} du contrôle). Le propionate (C3) augmentait avec les doses et la proportion la plus élevée était observée avec 8 mg de PA (P <0,001). La TDMO était similaire pour toutes les doses, à l'exception de 64 mg de PA, où une augmentation légère mais significative (P <0,001) a été observée (77,7%). La TDMO ne différaient pas entre les doses de PA, à l'exception de la dose de 64 mg, pour laquelle la valeur observée (77,7%) était significativement plus élevée (P <0,001) que toutes les autres (en moyenne73,1%). Les valeurs de PF étaient équivalentes pour toutes les doses (en moyenne 3,2), sauf pour 64 mg (P <0,0001). La même tendance a été observée pour MBM (p <0,001). Il a été conclu que la poudre d'ail pouvait présenter des avantages liés à ses actions antioxydante et antimicrobienne et pourrait être considérée comme une alternative naturelle aux antioxydants synthétiques. En outre, il s'est avéré modifier positivement les fermentations dans le rumen. Des mesures in vivo et des performances sont nécessaires pour confirmer les éventuels avantages positifs et pour étudier les effets de l'ail sur la digestion, les performances des animaux et la qualité du produit.

Mots-clés. *Ail – Composés secondaires – Antioxydant – Activités antimicrobiennes – Fermentation* in vitro *– Moutons.*

I – Introduction

Recently, the administration of antibiotics in animal feed as growing promoters is going to be increasingly alarming because of the emergence of potential bacterial resistance among animal food products consumers (Anassori *et al*., 2011).The utilization of antibiotics could result in the appearance of residues in the final animal products. This situation has prompted scientists to find other naturals alternatives. In this connection, researches have shown that many plants and their extracts have a very strong antibacterial activity and can be exploited to develop antibiotics activities for the treatment of humans and animals (Busquet *et al*., 2005; Castillejos *et al*., 2006). Aromatic plants are able to naturally produce biologically active metabolites (Khadri *et al*., 2010). Indeed, in addition to the primary metabolites, aromatic plants accumulate secondary metabolites. Among these plants, garlic *(Allium sativum* L.) is beginning to have much interest as a potential source of natural active bio-molecules in animal nutrition. Some research suggests garlic as a growth promoter in livestock (Yan and et al., 2011). Anassori *et al*. (2011) demonstrated that raw garlic and garlic oil resulted in a range of beneficial effects on rumen fermentation. This study was carried in order to evaluate the chemical composition, the secondary compounds contents and the antioxidant and the antimicrobial activity of a local Tunisian variety. Also, effect of garlic powder on *in vitro* rumen fermentation characteristics was investigated.

II – Materials and methods

Garlic *(Allium sativum)* was harvested from the region of Beja (Northern-west of Tunisia, humid). Samples were dried at 50°C during 48h, and then ground to pass through a 1 mm screen and stored for chemical analysis and other determinations.

Garlic powder was analyzed for dry matter (DM), ash and crude protein (CP) contents (AOAC, 1984). Cell wall composition in feeds (NDF, ADF and ADL) was analyzed as described by Van Soest *et al.* (1991).The total phenols content was determined using Folin-Ciocalteu reagent and gallic acid was used as standard (Lister and Wilson, 2001). Total flavonoids were measured by a colorimetric assay according to Dewanto *et al*. (2002) using te method based on the formation of flavonoid-aluminum complex.Tannins contents were determined as described by Joslyn (1970) and absorbance was measured at 760 nm after addition of Folin-Denis reagent and Na_2CO_3. Each assay was repeated in triplicate.

Antioxidant activity was evaluated as free radical scavenging capacity by measuring the scavenging activity of garlic extract on DPPH (Sánchez-González *et al*., 2011).

The ethanol and the methanol extract of garlic were individually tested for their antibacterial activity against Gram negative bacteria *(Escherichia coli* (E.coli)) and Gram positive bacteria *(Staphylococcus aureus* and *Bacillus subtulis*). Petri dishes were prepared and the discs with extract were applied. Bacterial strains were grown in trypto-caseine soja agar (TSA) and incubated at 37°C for 24 h. Antimicrobial activity was assessed as described by Teixeira *et al*. (2012). All these measurements were carried out in triplicates.

Rumen content was collected from 4 adult Barbarine sheep (average 12 months, 30 kg live weight) slaughtered at the municipal slaughterhouse of Ariana (Tunis). Animals were chosen in order to standardize the rumen fluid. The rumen contents of the 4 sheep (1L per animal) was collected immediately after evisceration and transferred in pre-warmed thermos flasks rapidly to the laboratory where the contents were mixed and filtered through 4 layers of surgical gauze.

A composed diet (D: 50% of ray-grass hay and 50% of commercial concentrate on DM basis) was used to determine the effect of growing doses (0, 4, 8, 16, 32 and 64 mg) of garlic powder on *in vitro* rumen fermentation parameters. Samples (0.5 g DM) of D were incubated in 100 ml glass syringes according to the technique of Menke and Steingass (1988). The incubation medium (50ml) was a mixture of rumen fluid and buffer solution (1:1). Gas production was measured at 1, 2,4, 6, 12 and 24 h of incubation. Diets were incubated in 5 replications (syringes) and in two successive batches. Each incubation lasted 24 h, then gas production and pH were measured. At the end of incubation, two syringes from each dose were reserved for NH_3-N and VFA analysis using gas chromatography.Three syringes were used to determine DMO. Cumulative gas production data were fitted according to the model of Orskov and McDonald (1979). The partitioning factor (PF) was calculated as the ratio between TODM (mg) and the gas produced at 24 hours of incubation of substrate truly degraded (Blümmel *et al*., 1997). The microbial biomass (MBM) yield was calculated using the TODM (mg) and gas volume (24 h) and stoichiometric factor (Blümmel *et al.,* 1997) as follows: MBM (mg) = substrate truly degraded (gas volume × stoichiometric factor), where the stoichiometric factor was equal to 2.25 (value used for roughages).

For the *in vitro* trial, the General Linear Model procedure (GLM) of SAS (2009) with the option of LS MEANS multiple ranges was used to analyze data. The model included effects of GP dose, incubation batch and interaction. The control syringes (T: containing buffered solution with inoculum) were used as co-variable in order to control rumen liquid variation.

III – Results and discussion

Chemical composition of garlic powder is presented in Table 1. Garlic is relatively high in CP (16.6% DM). Our results are very close to that reported by Kongmun *et al.* (2010) and Klevenhusen *et al.* (2011). The total cell wall content (NDF) of garlic was low (58 %DM). This value is higher than that found by Manasri *et al.* (2012) and Kongmun *et al.* (2011). The ADF fraction (6.5% DM) was also higher than the values reported by Kongmun *et al*. (2011) and Manasri *et al*. (2012). Garlic cell wall was very lowly lignified (ADL: 3.5% DM). Garlic contains various secondary compounds at different levels, such as phenols, flavonoids and tannins. Results of the quantitative determination of total phenol, flavonoids and total tannins are also reported in Table 1.

The obtained results of the antioxidant activity shows that the percentage inhibition of garlic was 155.16 µg/ml. Both ethanolic and methanolic extracts of garlic showed variable antibacterial activity against Gram (+) and Gram (–) strains. The ethanolic extract affected more the Gram (+) bacteria than the Gram (–) ones. Our results are in agreement with Gulfraz *et al.* (2011) who showed that the ethanolic extracts of garlic show an inhibitory activity against all bacteria tested Gram (+)

and Gram (–) with zones of inhibition between 10.3 (+/– 0.5 mm) and 14.3 (+/– 0.5 mm).The ethanolic extract has the strongest antibacterial activity against the different bacteria tested. This activity was more important against Gram (+) bacteria essentially against Staphylococcus aureus with a diameter of inhibition: 18 mm (ZouariChekki *et al*., 2014).

Table 1. Chemical composition of garlic used in the experiment (% of dry matter)

DM_F (%)	DM Powder (%)	Ash %DM	MO %DM	CP %DM	NDF %DM	ADF %DM	ADL %DM	Total polyphenols (mg/g eq.AG)	Flavonoids (mg EQ/g MS)	Tanins (mg EQ/g MS)
35.5	87.7	3.4	96.5	16.6	5.8	3.2	–	0.37	0.11	30.2

DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin.

In vitro results are reported in Table 2. Garlic powder increases significantly (P<0.001) gas production for 32 (104,32 ml) and 64 mg (108,64 ml). An increase (P<0.0001) in NH3-N concentration was recorded with doses 4 and 8 mg, compared with control; whereas adding 32 and 64 mg resulted in a NH3-N concentration equivalent to control (averaged 39.25 mg/100 ml). The total VFA concentration noted with control (73.6 $mmolL^{-1}$) was the lowest value (P<0.001). Adding GaP resulted in increased, but equivalent VFA concentrations for all the other doses (averaged 99,28 $mmolL^{-1}$). The propionate (C3) increased with garlic adding and a higher proportion was noted with all the supplemented samples (averaged 19,08%, *P* <0.001). Wanapat *et al.* (2008), reported that increased supplementation of garlic powder in diets resulted in increased C3 and C4 proportions. The authors reported that the increased proportion of C3 was simultaneous with a reduction of the proportion of C2.

Table 2. Effect of increasing doses of garlic powder on rumen fermentation

Dose (mg)	0	4	8	16	32	64	SEM
Gas 24 (ml)	86.31^{c}	87.07^{c}	88.08^{c}	91.53^{bc}	104.32^{ab}	108.64^{a}	1.39
pH	6	5.97	5.99	6.0	5.97	5.95	0.0259
NH_3-N (mg/100ml)	35.49^{c}	40.95^{a}	40.8^{a}	39.17^{b}	38.15^{bc}	40.25^{ab}	0.572
Total VFA ($mmolL^{-1}$)	73.6^{b}	133.5^{a}	142.2^{a}	133.69^{a}	122.96^{a}	136.35^{a}	15.1
$\%C_2$	62.81^{a}	57.86^{b}	58.86^{b}	58.53^{b}	57.87^{b}	59.86^{b}	0.93
$\%C_3$	17.54^{b}	19.01^{a}	19.04^{a}	19.2^{a}	18.95^{a}	19.19^{a}	0.32
$\%C_4$	11.5^{b}	15.14^{a}	15.23^{a}	15.23^{a}	15.72^{a}	14.95^{a}	0.83
C_2/C_3	3.55^{a}	2.92^{b}	3.09^{b}	3.06^{b}	3.01^{b}	3.12^{b}	0.07

$^{a, b, c, d}$. Values with different letters in the same line are statistically different, *** P<0.001, **** P<0.0001, SEM: Standard error of the mean.

Microbial activity results are presented in Table 3. The TOMD was similar for all the doses except for 64 mg GaP, where a slight but significant (*P* <0.001) increase was noted (77.7%; vs an average of 73.1% for all the others. PF values were equivalent in all doses (averaged 3.2), while a significant (*P* <0.0001) increase was noted with 64 mg. The same trend was observed in MBM (*P* <0.001). The current results with the dose of 64 mg may be related to the small amounts of nutriment supplied from garlic, and are in line with the increase in gas production registered at this dose (Anassori *et al.,* 2011).

Table 3. Effects of increasing doses of garlic powder on DMO, PF and MBM

Dose (mg)	0	4	8	16	32	64	SEM
TOMD (%)	64.58^{a}	64.22^{a}	67.04^{a}	69.74^{a}	68.34^{a}	77.7^{b}	0.009
PF	3.14^{cd}	3.09^{b}	3.39^{bcd}	3.48^{bc}	3.64^{bc}	4.45^{a}	0.1
MBM (mg)	99.09^{b}	115.93^{b}	133.27^{b}	158.62^{b}	187.72^{ab}	281.66^{a}	7.19

$^{a, b, c, d}$. Values with different letters in the same line are statistically different, *** P<0.001, **** P<0.0001, SEM: Standard error of the mean.

IV – Conclusions

Garlic powder was relatively high in CP. Extracts had different contents of secondary compounds. For the anti-microbial activity, methanol extract was more active against Gram (–) bacteria than ethanol extract. Garlic was found to modify positively rumen fermentations. Red garlic powder could present some feeding advantages related to its antioxidant and antimicrobial actions and could be considered as a natural alternative to synthetic antioxidants. Some interesting modifications in rumen fermentation trends were observed. The effects of garlic on animal performances and product quality, considering the corresponding doses are to be investigated.

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Use of tannins to protect insect meal protein against ruminal degradation in sheep

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Abstract. Due to the high dependence of ruminant feeding systems on the use of soybean meal as source of protein, insect meals have been suggested as a promising alternative. However, a high rumen degradability might be a drawback for its utilisation. In this regard, tannins are known to be able to exert beneficial effects on the digestive utilization of protein-rich feeds due to a reduction of their degradation in the rumen, especially of the protein, although they might also restrict intestinal digestibility. Therefore, this experiment was conducted to examine if tannins could improve the digestive utilization of 4 insect meals (from *Acheta domesticus*, *Alphitobius diaperinus*, *Tenebrio molitor* and *Zophobas morio*). To this aim, four ruminally cannulated sheep were used to study the ruminal degradation and intestinal digestibility of these feedstuffs as well as those of soybean meal, which was used as a reference. The five substrates were treated with either 0% (control) or 15% DM of commercial tannin extracts from oak (OAK) or quebracho (QUE), and incubated *in situ* for 16 h. Afterwards, the intestinal digestibility of non-degraded protein was estimated *in vitro*. Both oak and quebracho tannins were able to protect the protein of insect meals from ruminal degradation, following a similar pattern than that observed in soybean meal. On average, reductions were about 15%, with no significant differences between oak and quebracho effects. On the opposite, the OAK treatment might offer advantages over QUE in terms of intestinal protein digestibility, as the latter caused a lower value in *A. domesticus* compared with the control. More research would be advisable to confirm these results, particularly *in vivo*.

Keywords. Alternative feeds – Condensed tannins – Hydrolysable tannins – Digestive utilisation.

Utilisation de tanins pour protéger la protéine de farine d'insectes contre la dégradation ruminale chez les ovins

Résumé. *En raison de la forte dépendance à l'utilisation de tourteau de soja comme source de protéines dans les systèmes d'alimentation des ruminants, la farine d'insectes a été suggérée comme une alternative prometteuse. Cependant, une forte dégradation de sa protéine dans le rumen pourrait constituer un inconvénient à son utilisation. À cet égard, les tanins peuvent avoir des effets bénéfiques sur l'utilisation digestive des aliments riches en protéines, en réduisant leur dégradation dans le rumen, même si ils peuvent limiter la digestibilité intestinale. Par conséquent, cet essai a été mené afin d'examiner si les tanins pouvaient améliorer l'utilisation digestive de 4 farines d'insectes (provenant d'*Acheta domesticus, Alphitobius diaperinus, Tenebrio molitor *et* Zophobas morio*). Pour ce faire, quatre moutons munis d'une canule ruminale ont été utilisés afin d'étudier la dégradation ruminale et la digestibilité intestinale de ces aliments, en comparaison avec celles du tourteau de soja (aliment de référence). Les cinq substrats ont été traités avec 0 (témoin) ou 15% MS des extraits commerciaux de tanin de chêne (OAK) ou de quebracho (QUE) et par la suite ils ont été incubés in situ pendant 16 h. Ensuite, la digestibilité intestinale de la protéine non dégradée a été estimée in vitro. Les tanins de chêne et de quebracho ont permis de protéger la protéine des farines d'insectes de la dégradation ruminale, en suivant une tendance similaire à celle observée pour le tourteau de soja. En moyenne, la réduction de la dégradation protéique a été d'environ 15%, sans différence significative entre les effets du chêne et du quebracho. Au contraire, en termes de digestibilité intestinale des protéines, le traitement OAK pourrait offrir des avantages par rapport à QUE, puisque ce dernier a entrainé une valeur inférieure pour A. domesticus par rapport au contrôle. D'autres recherches seraient requises pour confirmer ces résultats, particulièrement en conditions* in vivo.

Mots-clés. *Aliments alternatifs – Tanins condensés – Tanins hydrolysables – Utilisation digestive.*

I – Introduction

Ruminant feeding systems are highly dependent on soybean meal as source of protein. This dependence is especially high in Europe due to the ban on the inclusion of meat and bone meals and their derivatives in ruminant diets, which obliges to employ almost exclusively protein of vegetable origin. Although the use of insects has been suggested as an alternative source of protein for livestock (Makkar *et al*., 2014), to date there are very few reports characterizing this type of protein feeds in ruminants (Jayanegara *et al*., 2017; Rashmi *et al*., 2018). No data on the extent of ruminal degradation of insect meal protein seems to be available in the literature.

In addition, it is known that tannins (both hydrolysable and condensed) can reduce the rumen degradation of dietary protein and thus improve the supply of amino acids susceptible of being absorbed in the intestine (Frutos *et al*., 2000; Hervás *et al*., 2000; Makkar, 2003). However, we are not aware of studies applying this treatment to protect insect meals.

Therefore, this trial was conducted to examine if tannins could reduce the ruminal degradation of insect meal protein without affecting its intestinal digestibility, thus improving its digestive utilization. To this aim, different insect meals were treated with oak and quebracho tannin extracts, and compared with soybean meal as a reference feed.

II – Materials and methods

Four ruminally cannulated Merino sheep (57.4 kg of body weight) were fed a total mixed ration (60:40 forage:concentrate ratio, 91.6% DM, 20.5% CP, 31.4% NDF) at 1.1 times their estimated maintenance energy requirements (approx. 900 g/animal and day).

Four insect meals were studied: (1) mealworms (*Tenebrio molitor*); (2) morioworms (*Zophobas morio*); (3) buffaloworms (*Alphitobius diaperinus*), and (4) adult domestic crickets (*Acheta domesticus*). In addition, soybean meal was used as a reference feed. Their chemical composition is reported in Table 1.

Table 1. Chemical composition of the meals[1]

	DM	OM	CP	NDF	ADF	EE	Starch
Soybean	87.5	93.1	50.6	14.5	9.3	3.5	0.3
Tenebrio molitor	93.2	96.6	50.9	19.5	7.6	34.4	4.5
Zophobas morio	93.7	96.6	37.8	9.6	5.3	48.8	1.8
Alphitobius diaperinus	93.3	96.0	64.7	11.4	7.3	24.7	0.9
Acheta domesticus	91.3	94.7	69.9	13.4	8.4	18.1	1.6

[1]DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; EE: ether extract. Results are expressed as % DM, except DM, which is expressed as % fresh matter.

Fifty g of each meal were ground (2 mm) with dry ice and treated with 15% DM of tannin extracts (Frutos *et al*., 2000; Hervás *et al*., 2000) by spraying 30 mL of distilled water with 7.5 g of a commercial tannin extract of oak (OAK, >65% tannins) or quebracho (QUE, ≥69% tannins), or with tannin-free water (Control treatment). The substrates were then dried at 45 ºC for 48 h.

The ruminal degradation of the meals was studied using the nylon bag technique (Ørskov and McDonald, 1979). These bags (50 μm pore size, R1020, Ankom Technology, USA) were filled with 6 g of substrate and incubated for 16 h in the rumen of the cannulated sheep. After removal from the rumen, the bags were washed with cold tap water and frozen (-30 ºC) for 24 h. Once defrosted, bags were washed again with cold water in a washing machine and dried in a forced-air oven at 45 ºC for 48 h to estimate DM disappearance (DMD). The residues were ground to 1 mm and CP concentration was analysed (ISO 5983-2:2009) to determine CP disappearance (CPD). The in-

testinal digestibility of the non-degraded protein (IDNDP) of each substrate was determined following the *in vitro* technique described by Calsamiglia and Stern (1995).

For each feed, results were submitted to ANOVA using the MIXED procedure of SAS (v9.4, SAS Inst. Inc., USA) with a model that included the fixed effect of treatment and the random effect of animal. Means were adjusted for multiple comparisons using Bonferroni's method.

III – Results and discussion

The treatment of soybean meal with tannins decreased CPD compared with the untreated meal (Table 2). The mean reduction was 15% and, although there were no significant differences between OAK and QUE, CPD was numerically lower in the first treatment, which would help explaining the reduction in DMD ($P<0.05$). This response was expected based on the known effect of tannins protecting the protein from ruminal degradation (Frutos *et al*., 2000; Dentinho *et al*., 2014). Similarly, it was predicted that the dose of tannins would not detrimentally affect the intestinal digestibility of non-degraded protein of this reference feed, although the use of higher doses or other tannin extracts might reduce it (Frutos *et al*., 2000; Hervás *et al*., 2000; Dentinho *et al*., 2014). Intestinal digestibility tended to be slightly higher in OAK than in QUE, but there were no significant differences compared with the control.

Table 2. Disappearances (g/g) of dry matter (DMD) and crude protein (CPD) after 16 h of incubation in the rumen, and intestinal digestibility (g/g) of the non-degraded protein (IDNDP) of feeds treated or not with 15% of a tannin extract from oak (OAK) or quebracho (QUE)

	Treatment				
	Control	OAK	QUE	SED[1]	Prob.[2]
Soybean meal					
DMD	0.893[a]	0.790[b]	0.837[ab]	0.0278	0.017
CPD	0.914[a]	0.736[b]	0.812[b]	0.0318	0.002
IDNDP	0.680	0.721	0.644	0.0234	0.062
Tenebrio molitor					
DMD	0.654	0.632	0.643	0.0107	0.190
CPD	0.486[a]	0.390[b]	0.417[b]	0.0094	<0.001
IDNDP	0.782[ab]	0.796[a]	0.723[b]	0.0234	0.028
Zophobas morio					
DMD	0.839[a]	0.786[b]	0.797[b]	0.0126	0.005
CPD	0.724[a]	0.574[b]	0.596[b]	0.0161	<0.001
IDNDP	0.703[b]	0.780[a]	0.702[b]	0.0157	0.001
Alphitobius diaperinus					
DMD	0.789[a]	0.714[b]	0.684[b]	0.0146	<0.001
CPD	0.778[a]	0.648[b]	0.620[b]	0.0176	<0.001
IDNDP	0.640[b]	0.780[a]	0.645[b]	0.0127	<0.001
Acheta domesticus					
DMD	0.702	0.679	0.680	0.0134	0.201
CPD	0.702[a]	0.635[b]	0.632[b]	0.0145	0.003
IDNDP	0.728[a]	0.757[a]	0.645[b]	0.0242	0.005

[a,b]Within a row, different superscripts indicate significant differences due to treatment ($P<0.05$).

[1]Standard error of the difference. [2]Probability.

The CPD of insect meals followed the same pattern of variation as in the soybean meal, with OAK and QUE reducing its value in all cases (P<0.05). Decreases ranged from 10% in *A. domesticus* to 19% in *Z. morio*, but no apparent relationship was observed between the magnitude of the response and the initial CP value of each insect or its CPD in the control. This latter parameter was relatively low in *T. molitor*, which would limit the interest of using tannin extracts to further decrease it. Consistent with soybean meal, results of CPD may also explain changes in DMD in *Z. morio* and *A. diaperinus* (-6 and -11%, respectively). We are not aware of other publications on the protection of insect protein against ruminal degradation.

Similarly, in the absence of available data in the literature, the effect of tannins on the intestinal digestibility of insect protein can only be compared with vegetable protein-rich feeds. The IDNDP of insects was similar or higher than that of soybean meal and, as indicated for the latter feed, it was higher in OAK than in QUE for all of them (P<0.05) and, surprisingly, also than in the control for *Z. morio* and *A. diaperinus*. Although previous studies had shown reductions or no effects of tannins on intestinal digestibility (Hervás *et al*., 2000; Makkar, 2003; Dentinho *et al*., 2014), it could be speculated that differences between OAK and QUE in the breakdown of tannin-protein complexes as well as a partial degradation in the rumen of the hydrolysable tannins from oak might help to explain our results. In any event, although OAK could be suggested to be more advantageous than QUE to improve the digestive utilization of insect protein, further studies must be conducted to confirm our observations, particularly *in vivo*. The economic cost of each extract must also be evaluated before selection. Similarly, additional research would be advisable to examine the responses to lower tannin doses, extracts of lower purity or from different origins, with the ultimate goal of minimising costs under practical conditions. Finally, given the high fat content of some insects (Table 1), it would be of great interest to characterize the effect of these nutritional strategies on ruminal lipid metabolism, because some tannins have been shown to favour the ruminal accumulation of certain desirable fatty acids (e.g., linoleic, α-linolenic and vaccenic acids, Toral *et al*., 2018).

IV – Conclusions

Treating insect meals with 15% of tannin extracts from oak or quebracho is effective to protect their protein from ruminal degradation. Concerning the intestinal digestibility of non-degraded protein, oak tannins seem more advantageous than those of quebracho in some cases.

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Effect of animal species and supplementary feeding on digestion and energy utilization by sheep and goats grazing arid-area rangelands

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Abstract. Fifty-two non-productive females, 26 Balady goats and 26 Abu-duleik sheep, were employed in a 2.5-month experiment to study the effects of animal species and supplementation level on intake, digestion and energy utilization. Animals of each species were divided into two treatments. They all were grazing arid-area rangelands with a limited amount of concentrate supplement, low (1% BW) or high (2% BW). Total energy expenditure (EE) was estimated by heart rate monitors for 48h after individual calibration by oxygen consumption with a face mask open-circuit respiratory system. Acid insoluble ash (AIA), as an internal marker, was used to estimate the individual intake and digestibility for 6 animals per treatment, while bags were used for total fecal collection. Increasing the concentrate supplement level had negative effects on forage intake and digestibility of grazing goats, while the contrary was observed in sheep. The reduction in goat's digestibility was mainly attributed to the reduction in fiber fraction digestibility. However, grazing sheep supplemented with a high concentrate level consumed more forage and had a higher digestibility, including fiber fraction digestibility. Total EE was similar between animal species at a low supplementation level and significantly increased with a high level in sheep, but not in goats. Energy balance (EB) was negative and similar between animal species at a low supplementation level, while sheep reported positive and better EB than goats with a high level. In conclusion, supplementary feeding is essential to maintain the animals without deterioration while grazing arid-area rangelands but its effects varied between sheep and goats when supplied at a high level (2% BW).

Keywords. Grazing – Arid-area rangelands – Supplementation – Digestion – Energy utilization – Sheep and goats.

Effet de l'espèce animale et la supplémentation alimentaire sur la digestion et l'utilisation de l'énergie par les ovins et les caprins conduits sur parcours en zones arides

Résumé. *Cinquante-deux femelles taries et non gravides, 26 chèvres de race Balady et 26 brebis de race Abu-duleik ont été utilisées, dans un essai d'une durée de 2,5 mois, pour étudier l'effet de l'espèce animale et la supplémentation alimentaire sur l'ingestion, la digestion et l'utilisation de l'énergie. Les animaux de chaque espèce ont été divisés en deux traitements. Tous les animaux pâturaient sur des parcours des zones arides avec une quantité limitée de supplément de concentré niveau faible (1% de poids vif) ou niveau élevé (2% de poids vif)). La dépense énergétique totale (EE) a été estimée en utilisant un moniteur de fréquence cardiaque (HR) pendant 48h après un étalonnage individuel de la consommation d'oxygène avec un masque respiratoire facial ayant un système de circuit ouvert. Les quantités ingérées individuelles, de six animaux de chaque traitement, ont été déterminées en estimant la digestibilité (en utilisant les cendres insolubles dans l'acide (AIA) comme marqueur interne) et mesurant la production totale de fèces (sacs de collecte fécale). L'augmentation du niveau de supplémentation a eu des effets négatifs sur la consommation de fourrage et la digestibilité chez les chèvres au pâturage, alors que chez les brebis, le contraire a été observé. La diminution de la digestibilité chez chèvres est due principalement à la réduction de la digestibilité des fractions de fibres. Cependant, les brebis au pâturage et supplémentées avec le niveau élevé de concentré ont consommé plus de fourrage et ont eu une digestibilité supérieure (y compris la digestibilité de la fraction de fibres). L'EE totale a été similaire entre les ovins et les caprins avec le faible niveau de supplémentation, par contre, elle a augmenté significativement avec le niveau élevé de supplémentation chez les ovins en comparaison avec les chèvres. Le bilan énergétique (EB) a été négatif et similaire entre les deux espèces animales avec le faible niveau de supplémentation, tandis que les brebis ont eu un EB positif et meilleur que les chèvres avec le niveau élevé de supplémentation. En conclusion, la supplémentation alimentaire est essentielle pour maintenir les animaux sur parcours en zone aride sans détérioration, mais ses effets varient entre les ovins et les caprins avec le niveau élevé (2% PV) de concentré.*

Mots-clés. *Pâturage – Parcours de zone aride – Supplémentation – Digestion – Utilisation d'énergie – Ovin-caprin.*

I – Introduction

Sheep and goats are very important to the world's food security and supply because of their ability to utilize fibrous materials not of immediate nutritional value of people. They also affect the social and economic status of people inhabiting arid and semi-arid regions. The efficiency of forage utilization is affected by many factors such as animal species and supplementary feeding (NRC, 2007). Feeding supplementation may be necessary to cover the nutrient requirements of grazing animals, particularly in the dry season. Supplementation may also affect the forage intake and digestibility (Askar *et al*., 2014). It decreases time spent grazing and associated energy cost for grazing activity (Beker *et al*., 2009), improving the efficiency of nutrient utilization. The objective of this study was to determine the effect of supplementary feeding on energy utilization by sheep and goats grazing arid rangelands and supplemented with two concentrate supplement levels.

II – Material and methods

The study was carried out in the Ras Hederba Valley region at the Shalateen research station of the Desert Research Center, some 1300 km south east of Cairo, the capital of Egypt. The full description of the area is mentioned in Askar *et al*. (2014).

Animals and treatments: Fifty-two non-productive females, 26 Balady goats and 26 Abu-duleik sheep (hair coat breed), were employed in a 2.5-month experiment to study the effects of animal species and supplementary feeding level on intake, digestion and energy utilization. Animals of each species were divided into two treatments, 13 per each. They were grazing arid rangelands with a limited amount of concentrate supplement, low (1% BW) or high (2% BW).

Experimental procedures: The experiment started in July 2013 and lasted for 2.5 months, including a 2-week final period for the measurements of feed intake, digestibility and energy utilization. Concentrate supplement was given in the morning (before grazing). Water was available free choice twice daily, at 08:00 and 14:00 h. The acid insoluble ash (AIA), as an internal marker, was used to estimate the individual intake and digestibility for 6 animals per each treatment, while bags were used for total fecal collection.

Energy expenditure: The calorimetry system and its usage were described previously by Askar (2016). Animals were fitted with a face mask facilitating open-circuit respiratory system for measuring O2 consumption (Sable Systems, Las Vegas, NV). Heart rate (HR) was simultaneously measured to determine the individual energy expenditure (EE)/HR ratio. Energy expenditure was estimated assuming a constant thermal equivalent of 20.47 kJ per liter O2. Human S610 HR (Polar, Lake Success, NY) monitors with infrared connections to the transmitters were used to collect HR data at a 1-min interval. Heart rate data were analyzed using Polar Precision Performance SW software provided by Polar. Heart rate was measured for each animal while grazing for at least 48h. The daily EE was determined from the EE: HR ratio of each animal. Furthermore, Gross energy (GE) of feed, orts and feces were estimated by bomb calorimeter (IKA, model C 200, Staufen, Germany), using benzoic acid as standard. Metabolizable energy (ME) was estimated as 82% of digestible energy (DE) intake (NRC, 2007). Energy balance (EB) was calculated as the difference between ME intake (MEI) and EE.

Statistical analyses: Data were analyzed by the GLM procedure of the SAS statistical package. The model included the effects of animal species, supplementation level, and their interaction. The least significant difference (LSD) was used to compare the means, and differences with $P<0.05$ were accepted as statistically significant.

III – Results and discussion

Intake and digestibility: Although a similar forage intake was observed in grazing sheep and goats receiving a low supplementation level, a significant reduction in forage intake was observed in goats *vs* sheep receiving a high level. Roughage to concentrate ratio in the diet was similar (67.6%) for sheep and goats at a low supplementation level, while this ratio was significantly varied and dropped to be 43.8 vs. 53.9%, respectively, at a high level. However, lower forage intake in goats was associated with a significant reduction in nutrient digestibility, particularly for those related to fiber fraction digestibility (Table 1). Results are in agreement with Allam *et al*. (2007) who worked on the same goat breed supplemented with two concentrate levels, 25 and 50% of ME, and grazing similar arid-area rangelands. It was expected that increasing concentrate supplement intake might negatively affect forage intake and digestibility (Garcés-Yépez *et al*., 1997). This would be attributed to its negative effects on rumen pH and cellulolytic bacteria (Mann and Ørskov, 1975). Increasing concentrate supplement in diet might also negatively affect protozoa population, sometimes leads to their disappearance in the rumen (McAllister and Cheng, 1996), and the efficiency of microbial protein synthesis. On the other hand, this is not the case with sheep in which forage intake was increased by increasing the concentrate supplement level. Our results also showed that increasing the supplementation level improved the forage intake and digestibility in sheep. The findings are in agreement with our previous results with the same sheep breed and under similar grazing condition (Askar *et al*., 2014). Moreover, concentrate supplement was reported to increase forage intake and utilization as a result of increasing dry matter digestibility (Gekara *et al*., 2005). It was reported that the effects of concentrate supplement on forage intake vary depending on the forage quality and supplement composition (Moore *et al*., 1999). In agreement with the current findings in sheep, supplementary feeding was not observed to affect forage intake when the forage quality was high (Kartchner, 1980; Smith *et al*., 2006), while supplementation was reported to positively affect the intake of low quality forage (Kartchner, 1980).

On the other hand, faster fractional rates of passage of digesta from the rumen were reported in goats vs. sheep when they grazed in semiarid-area rangelands (García *et al*., 1995). This might negatively affect rumen retention time and consequently fiber fraction digestibility in goats. Moreover, in the current study, increasing concentrate level, which was accompanied by increasing total feed intake, may accelerate the rate of passage from rumen and increase the associated negative effects in goats.

Table 1. Feed intake and digestibility in sheep and goats grazing arid-area rangelands with different concentrate supplement levels, low (1% of BW) or high (2% of BW)

	Goats		Sheep		SEM	Significant		
	Concentrate supplement							
	Low	High	Low	High		Species	Treat	S*T
DM intake, g/ kg $BW^{0.75}$/ day								
Forage	47.0^{b}	36.0^{c}	51.8^{ab}	58.8^{a}	2.92	***	ns	**
Total	69.6^{c}	82.2^{b}	76.5^{bc}	109.2^{a}	2.67	***	***	***
Digestibility, %								
DM	58.2^{ab}	54.5^{b}	54.5^{b}	60.3^{a}	2.01	ns	ns	*
Energy	59.1^{a}	56.0^{b}	57.9^{ab}	62.3^{a}	1.74	ns	ns	*
NDF	54.6^{a}	44.1^{b}	51.3^{a}	54.4^{a}	2.40	ns	ns	**
ADF	49.9^{a}	36.5^{b}	45.5^{a}	48.3^{a}	2.89	ns	ns	**

$^{a, b, c}$ Means without a common superscript letter in the row are different (P < 0.05) among species x treatments. ns = non-significant; * = P < 0.05; ** = P < 0.01 *** = P < 0.001; SEM = Standard error of means.

Energy utilization: The GE, DE, and ME intake (kJ/ kg MBW, Table 2) are following the same trend of total dry matter intake. However, the EE (kJ/ kg MBW) was similar between sheep and goats when receiving a low supplementation level, while it was significantly (P<0.001) greater for sheep vs. goats when receiving a high level (Table 2). The differences between sheep and goats received different concentrate levels in the estimated EE were consistent throughout the day as shown by the evolution of daily records illustrated in Fig. 1. A higher intake of grazing sheep supplemented with high concentrate level was associated with a higher EE. In this regard, a positive relationship between feed intake level and EE was previously reported (Askar 2016; Askar *et al*., 2016).

Table 2. Energy utilization by sheep and goats grazing arid-area rangelands with different concentrate supplement levels, low (1% of BW) or high (2% of BW)

	Goats		Sheep			Significant		
Energy utilization,	**Concentrate supplement**				**SEM**			
kJ/ kg $BW^{0.75}$/ day	**Low**	**High**	**Low**	**High**		**Species**	**Treat**	**S*T**
Gross energy	1048^{c}	1261^{b}	1151^{bc}	1662^{a}	38.9	***	***	***
Digestible energy	622^{c}	707^{b}	664^{bc}	1033^{a}	27.6	***	***	***
Metabolizable energy	510^{c}	580^{b}	545^{bc}	847^{a}	22.7	***	***	***
Energy expenditure	560^{b}	577^{b}	600^{b}	776^{a}	23.9	***	***	***
Energy balance	-50.0^{c}	2.6^{b}	-56.0^{c}	71.5^{a}	9.41	***	***	***

$^{a, b, c}$ Means without a common superscript letter in the row are differed (P < 0.05) among species x treatments.
*** = P < 0.001; SEM = Standard error of means.

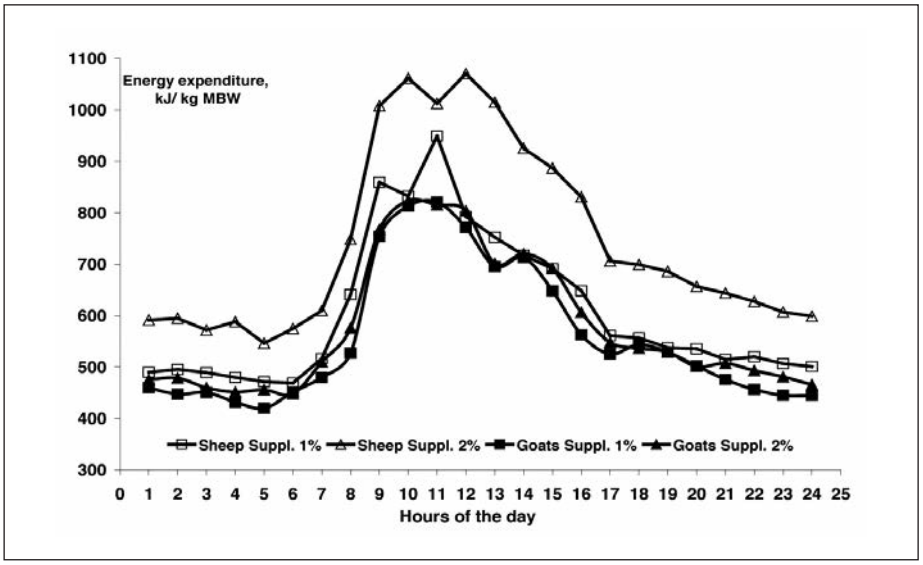

Fig. 1. Hourly energy expenditure (kJ/kg MBW) of sheep and goats grazing the arid-area rangelands with different concentrate supplement levels throughout 24-hour period.

On the other hand, a similar EE/ME intake ratio for sheep and goats receiving a low supplementation level (EE = 110% of ME intake), while a lower and an efficient ratio for sheep *vs* goats receiving a high level (EE = 92 *vs* 100% of ME intake, respectively) were observed. This indicated that sheep are in a better state than goats when supplemented with a high concentrate level. This is reflected on the EB that was negative and similar between animal species at a low supplementation

level, while sheep reported positive and better EB than goats with a high level, indicating that concentrate supplement is necessary to maintain animals while grazing arid-area rangelands as suggested by Askar *et al*. (2014), but its effects varied between sheep and goats at a high level.

IV – Conclusions

Supplementary feeding is essential to maintain animals without deterioration while grazing arid-area rangelands but its effects varied between sheep and goats when supplied at a high level (2% BW).

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Effect of different protein sources in ensiled sugar beet pulp-based diets on the performance of fattening lambs

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Abstract. The aim of this study was to compare the effects of using different sources of protein in ensiled sugar beet pulp-based diets on production performance of lambs. Eighteen Moroccan synthetic breed lambs "Dman*Boujaad" (19.7±1.07 kg initial body weight) were used to carry out this trial during 70 days preceded by a period of 15 days of adaptation to the experimental diets. Lambs were randomly assigned to three treatments (6 animals per treatment) and received a diet containing ensiled sugar beet pulp, barley straw, maize grain and three different protein sources: T_{TTS} (sunflower meal), T_{TS} (soybean meal) and T_{urea} (urea). Lambs were weighed at the beginning and at the end of the trial, and fortnightly in order to determine dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR) and feeding cost. The average daily gain was affected by the type of protein source (P<.0001). It was 173.4, 244.5 and 91.1 g/d for T_{TTS}, T_{TS} and $T_{urea,}$ respectively. Feed conversion ratio (kg DMI/kg ADG) was 6.65, 4.70 and 9.21 for T_{TTS}, T_{TS} and T_{urea}, respectively. The feeding cost (Moroccan dirham (MAD)/kg ADG) was 20.5, 16.3 and 26.6 for T_{TTS}, T_{TS} and T_{urea}, respectively. The inclusion of soybean meal in ensiled sugar beet pulp-based diets improves fattening performance of lambs.

Keywords. Protein source – Ensiled sugar-beet pulp – Lamb – Fattening.

Effets de différentes sources protéiques des rations à base de pulpe de betterave ensilée sur les performances d'engraissement des agneaux

Résumé. *L'objectif de ce travail était de comparer les effets de différentes sources protéiques dans les régimes à base de pulpe de betterave ensilée sur les performances d'engraissement des agneaux d'engraissement. Ainsi, Dix-huit agneaux de race synthétique "Dman * Boujaad" (19,7 ± 1,07 kg de poids vif) ont été utilisés pour mener cet essai durant 70 jours précédée par 15 jours d'adaptation aux régimes alimentaires. Les agneaux ont été répartis au hasard en trois traitements (6 agneaux chacun) et recevaient une ration contenant la pulpe de betterave ensilée, la paille d'orge, le maïs et trois différentes sources protéiques : T_{TTS} (tourteau de tournesol), T_{TS} (tourteau de soja et T_{urea} (Urée). Les agneaux ont été pesés au début et à la fin de l'essai et tous les quinze jours afin de déterminer le gain moyen quotidien (GMQ), l'indice de consommation (IC) et le cout alimentaire (CA). Le régime alimentaire a affecté significativement le GMQ (P<0,0001), les valeurs enregistrées sont 173,4, 244,5 et 91,1 g/j respectivement pour T_{TTS}, T_{TS} et $T_{urée}$. L'indice de consommation (Kg MSI/ KG GMQ) était de 6,65; 4,70 et 9,21 respectivement pour T_{TTS}, T_{TS} et T_{urea}. Le coût alimentaire (MAD/Kg GMAQ) était de 20,5, 16,3 et 26,6 respectivement pour T_{TTS}, T_{TS} et T_{urea}. L'incorporation de tourteau de soja dans une ration à base de pulpe de betterave ensilée améliore les performances d'engraissement des agneaux.*

Mots-clés. *Source protéique – Pulpe de betterave ensilée – Agneaux – Engraissement.*

I – Introduction

Silage of sugar beet pulp is a technique recently introduced in Morocco allowing to reduce the preservation cost of this by-product in comparison with the dehydration technique. Karalazos and Giouzeljannis (1988) reported that sugar beet pulp can be ensiled when its dry matter content is

greater than 15%. In addition, Martelli *et al*., (1999) indicated that nutritional qualities of ensiled sugar beet pulp are well preserved or even improved.

Several studies are shown that the use of ensiled sugar beet pulp has a high feed value and a positive effect on ruminal fermentation (Rohr *et al*., 1986). In this regards, Murphy (1986) reported that the nutritional value of this feed is comparable to barley forage.

For a better utilization of this resource in ruminant diets, the choice of an adequate protein source is essential to ensure a good synchronization of energy and protein intake and therefore a better functioning of the ruminal microbiota. The objective of this work was to evaluate the effect of the nature of nitrogenous source in ensiled sugar beet pulp-based diets on the fattening performance of lambs.

II – Material and methods

Eighteen Moroccan synthetic breed lambs "Dman*Boujaad" with initial weight of 19.7±1.07 and age of 120 ± 20.4 days were used to carry out this experiment during 70 days preceded by 15 days for diet adaptation. Lambs were randomly assigned to three treatments (6 animals per treatment) and received a diet containing ensiled sugar-beet pulp, barley straw, maize and three different nitrogenous sources: T_{TTS} (sunflower meal), T_{TS} (soybean meal) and T_{urea} (urea). Diets are distributed as total mixed ration (TMR) twice daily (at 9h and 12h). All used diets are isoenergetic. Ingredients and chemical composition of used diets in this trial are presented in Table 1.

Table 1. Ingredients and chemical composition of experimental diets

	Diet		
	T_{TTS}	T_{TS}	T_{urea}
Ingredients (%, Dry matter weight basis)			
Ensiled sugar beet pulp	30	30	30
Wheat straw	30	35	33
Maize grain	10	13	32
Sunflower meal	30	0	0
Soybean meal	0	22	0
Urea	0	0	5
Chemical composition (% Dry matter)			
Dry matter	68.7	67.8	68.2
Organic matter	94.7	94.7	96.0
Ash	5.3	5.3	4.0
Crude protein	13.3	16.2	20.7
Neutral detergent fiber	50.3	41.7	39.9
Acid detergent fiber	36.7	30.2	27.4
Lignin	8.6	5.8	5.2
Fat	1.7	1.8	2.0

T_{TTS}: Diet containing sunflower meal as protein source; T_{TS}: Diet containing soybean meal as protein source; T_{Urea}: Diet containing urea as protein source.

The intake amounts were determined daily. Lambs were weighed before morning feeding, at the beginning and the end of the trial and every 15 days during the trial. Free clean water and mineral block were available all the time.

The effect of the nature of nitrogenous sources used in the diet on final weight and average daily gain (ADG) was analyzed was analyzed by means of a one-way analysis of variance according to the model: $Y_{ij} = \mu + T_i + \varepsilon_{ij,}$ where T_i represents the diet effect and ε_{ij} the experimental error. The PROC GLM procedure of the SAS statistical package was used for the analysis. Comparisons among mean values were tested using the LSD test.

III – Results and discussion

1. Fattening performances

Table 2 shows the fattening performances of lambs fed diets containing different protein sources. Lambs fed ensiled sugar beet pulp-based diet with soybean meal as protein source (T_{TS}) presented the higher performances (P <0.01) in comparison with lambs fed T_{TTS} and T_{Urea}. The lowest final body weight and average daily gain were recorded in lambs receiving urea as protein source in the diet, while lambs fed T_{TTS} diet achieved intermediate performances. This difference might be due, in addition to the nature of the protein source, to the protein content of the different diets.

Our obtained results were superior to values reported by Deniz *et al*., (2002) on fattening lambs using 4 diets: EM (corn silage), F (grass hay), SBPSM (beet silage + 1 % urea + 5% beet molasses) and SBPHM (beet silage + 0% urea + 5% beet molasses)). The ADG found over a 60-day period are 4.62; 5.93; 2.85 and 3.45 kg for EM, F, SBPSM and SBPHM, respectively.

Table 2. Fattening performance of lambs fed diets with different nitrogenous sources

	Diet			SEM	P
	T_{TTS}	T_{TS}	T_{Urea}		
Initial body weight (kg)	18.6	17.6	18.3	–	–
Final body weight (kg)	33.1[a]	36.5[a]	24.6[b]	1.74	0.0013
Average daily gain (g/d)	173.5[b]	244.5[a]	91.2[c]	13.49	<.0001

T_{TTS}: Diet containing sunflower meal as protein source; T_{TS}: Diet containing soybean meal as protein source; T_{Urea}: Diet containing urea as protein source; SEM: standard error of the mean; P: probability of the differences; [a,b,c] Means with different superscripts are significantly different (P<0.05).

2. Intake, feed conversion and feeding cost

The obtained results related to the intake, feed conversion ratio and feeding cost are shown in Table 3. The intake amounts were 1.14, 1.13 and 0.82 kg DM/d for T_{TTS} T_{TS} and T_{Urea}, respectively. The low feed intake in T_{Urea} lambs may be due to ammonia nitrogen produced in the rumen (Bartley and Deyoe, 1975). The feed conversion ratio was 6.65, 4.7 and 9.21 Kg DMI/ kg ADG for T_{TTS} T_{TS} and T_{Urea}, respectively. The feeding cost was 20.52, 16.30 and 26.62 MAD/kg ADG for T_{TTS} T_{TS} and T_{Urea}, respectively. T_{TS} diet showed the lowest feed conversion and feeding cost, which may be to the high content of essential amino acids such as lysine and methionine in the soybean meal (Huber, 1991). Satter and Roffler 1975) reported that urea use is better when incorporated with a rapidly fermentable energy source.

Table 3. Intake, feed conversion and feeding cost of ensiled-sugar-beet-pulp based diets containing different protein sources

	Diet		
	T_{TTS}	T_{TS}	T_{urea}
Intake (kg DM/d)	1.14	1.13	0.82
Feed conversion (kg DMI/kg ADG)	6.65	4.70	9.21
Feeding cost (MAD/kg ADG)	20.52	16.30	26.62

T_{TTS}: Diet containing sunflower meal as protein source; T_{TS}: Diet containing soybean meal as protein source; T_{Urea}: Diet containing urea as protein source; DMI: Dry matter intake; ADG: Average daily gain; MAD: Moroccan dirham (1 MAD= 0.09 €).

IV – Conclusions

The results of this work show that soybean meal is a good protein source in an ensiled sugar beet pulp based diets for lamb fattening. However, the inclusion of urea at a level of 5% does not present a good alternative to reduce the feeding cost and feed conversion. From these results, it is interesting to carry out others trials in order to find the adequate incorporation level of urea in ensiled sugar beet pulp based diets.

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Faecal near infrared spectroscopy (FNIRS), a support tool to manage small ruminants

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Abstract. Faecal near infrared spectroscopy (FNIRS) can be a good technique to predict functional properties like intake or *in vivo* digestibility of forages by small ruminants. Data were collected from 108 different digestibility indoor and outdoor trials in Senegal and France carried out from 1993 to 2013 on sheep fed with a large variety of forage species. Faecal samples were scanned by a Foss NIRSystem 5000 monochromator. Calibrations were established on indoor trials samples and performed using the modified partial least square (mPLS) procedure to estimate dry or organic matter (DMI, OMI, g/kg metabolic weight, $BW^{0.75}$) intake, *in vivo* dry and organic matter (DMD, OMD, %) digestibility. The derived standard errors of calibration (SEC) and coefficients of determination (R^2cal) were 6.52 g/kg $BW^{0.75}$ and 0.81 for DMI, 5.17 g/kg $BW^{0.75}$ and 0.86 for OMI, 1.50% and 0.93 for DMD and 1.95% and 0.88 for OMD, respectively. These values confirm the interest of the use of FNIRS as a tool to manage small ruminants. The results obtained show a good accuracy with values similar to other published results for intake and digestibility. Validation on outdoor trials samples show the difficulty to extrapolate the prediction of intake with limited samples number and only one pasture quality.

Keywords. Near infrared spectroscopy – Faeces – Digestibility – Feed intake.

La spectroscopie proche infrarouge fécale (FNIRS), un outil de pilotage pour la gestion des petits ruminants

Résumé. *La spectroscopie proche infrarouge fécale (FNIRS) peut être une bonne technique pour prédire des propriétés fonctionnelles comme l'ingestion ou la digestibilité des fourrages par les petits ruminants. Les données proviennent de 108 essais de digestibilité différents en cage ou au pâturage réalisés au Sénégal et en France entre 1993 et 2013 sur des ovins incluant une grande variété d'espèces fourragères. Les échantillons de fèces ont été scannés avec un monochromateur Foss NIRSystem 5000. Les étalonnages ont été effectués avec la procédure des moindres carrés partiels modifiée (mPLS) avec les échantillons des essais en cages pour estimer l'ingestion de matière sèche ou de matière organique (DMI, OMI, g/kg^{0,75}), la digestibilité de la matière sèche ou de la matière organique (DMD, OMD, %). Les erreurs standard d'étalonnage (SEC) et les coefficients de détermination (R^2cal) étaient respectivement de 6,52 g/kg^{0,75} et 0,81 pour DMI, 5,17 g/kg^{0,75} et de 0,86 pour OMI, 1,50% et 0,93 pour DMD et 1,95% et 0,88 pour OMD. Ces valeurs confirment l'intérêt de la FNIRS comme outil de pilotage pour la gestion des petits ruminants. Les résultats obtenus montrent une bonne précision avec des valeurs similaires à celle rencontrées dans la bibliographie. Une validation sur les échantillons des essais au pâturage montre la difficulté d'extrapolation des étalonnages pour la prédiction de l'ingestion lorsque le nombre d'échantillons est limité et restreint à une seule situation.*

Mots-clés. *Spectroscopie proche infrarouge – Fèces – Digestibilité – Ingestion.*

I – Introduction

The understanding and management of ruminant husbandry require the measurement of functional properties such as intake or digestibility. These measurements require animal trials that are costly and time-consuming to implement either in the case of animals in metabolism cages or even more

in the case of animals in grazing conditions. The indirect measurement by faeces spectrum pioneered by Lyons and Stuth (1992) and well described by Stuth *et al.* (2003) makes it possible to obtain less-expensive information on the performance of animals in order to support livestock management. The use of a simple and fast technique such as near infrared spectroscopy (NIRS) to predict these functional properties is well established (Bastianelli *et al.*, 2018). Faecal NIRS is therefore an interesting alternative to tedious reference methods, particularly in some tropical countries where the technical and economic conditions are difficult to set up animal trials at experimental stations. In this work, we evaluate the capacity of our database collected during 20 years with various animal trials to contribute to support the management of small ruminants by predicting digestibility and intake.

II – Materials and methods

1. Samples and trials conditions

A total of 1321 samples of faeces were collected either at the rectal level or on total faeces collection during 108 different indoor (100) and outdoor (8) animal trials in Senegal (65) and France (43) from 1993 to 2013 on sheep. In Senegal, trials were conducted with individual metabolism crates only at the ISRA-LNERV Experimental Unit in Dakar. In France, trials were conducted at the Montpellier-Vauguières Experimental Unit (INRA-PHASE, UMR SELMET) in the south of France and at the La Fage experimental farm unit (INRA-GenPhyse) in a semi-mountainous area. The 8 outdoor trials were conducted at La Fage on about 0.5 ha rangeland paddocks (fertilized or not) with a stocking rate of 58 ewe lambs and suckling ewes per/ha. Sheep were equipped with a bag for collecting total faeces. Dry (DMD) and organic (OMD) matter digestibility were estimated with the *in vitro* pepsine cellulase method (Aufrère *et al.*, 2007) on hand clipped forages collected on the same paddocks. Dry (DMI) and organic (OMI) matter intake were calculated with total faeces and DMD and OMD respectively. One indoor trial was conducted with three groups of about 10 sheep fed in group for which DMI and OMI were measured. For other indoor trials, sheep were placed in individual metabolism crates. Several forage species were evaluated, either as a monoculture or multispecies meadows or dehydrated feed according to the trial. All faeces were dried (48h, 60°C) and ground through a 1-mm sieve before NIRS measurements.

According to the objectives of the different trials, DMI and OMI (g/kg metabolic weight, $BW^{0.75}$) were measured or estimated (outdoor trials) and *in vivo* DMD and OMD (%) were measured (indoor trials) and assembled into our database. The description of the database used for calibrations based on indoor trials only, is detailed in Table 1.

Table 1. Descriptive statistics of the faecal database used for calibrations (n = 1321)

Parameter	N	Min.	Max.	Mean	S.D.
DMI (g/kg $BW^{0.75}$)	677	25.00	112.00	73.40	16.04
OMI (g/kg $BW^{0.75}$)	659	30.00	104.00	69.51	14.19
DMD (%)	259	48.92	83.00	57.77	7.53
OMD (%)	109	52.65	79.60	63.50	6.04

N: number of observations; Min.: minimum value; Max.: maximum value; S.D.: standard deviation; DMI: dry matter intake; OMI: organic matter intake; DMD: *in vivo* dry matter digestibility; OMD: *in vivo* organic matter digestibility.

2. NIRS measurements

The samples of faeces were scanned on a Foss NIRSystem 5000 monochromator (Silver Spring, MD, USA). Measurement was done in reflectance mode in small circular cups (diameter: 50 mm) with quartz glass. Spectral data were collected every 2 nm from 1100 to 2500 nm as log 1/R. Samples were scanned in duplicate (two different cup fillings) and spectra were averaged. The NIRS calibration was performed using the modified partial least squares regression (mPLS procedure, WinISI software, Infrasoft Int., Port Matilda, PA, USA). Mathematical pre-processing was applied to spectra with detrending and normalization of data, and use of the second derivative calculated on five consecutive points with a smoothing also on a gap of five points (SNV-D 2,5,5). In order to evaluate the capacity of the models to be used on animals in grazing conditions, spectra from indoor trials were used as calibration set and spectra from outdoor trials as validation set. During the calibration process, prediction outliers (studentized residual T>2.5) were discarded. Cross-validation based on dividing the database into four groups of samples was used to select the optimum number of terms. Criteria for the evaluation of the prediction models are: SEC (standard error of calibration), SECV (standard error of cross-validation), which is an estimate of precision that can be expected in routine analysis, R^2cal (coefficient of determination of calibration) and R^2cv (coefficient of determination of cross-validation). Validation performance for the models was assessed by SEP (standard error of prediction) and R^2val (coefficient of determination of validation).

III – Results and discussion

The performances of the different calibrations obtained are presented in Table 2. For DMI, the SEC of 6.52 g/kg $BW^{0.75}$ and the SECV of 6.86 g/kg $BW^{0.75}$ or the R^2cal of 0.81 and the R^2cv of 0.79 are similar to the values reported by Andueza *et al*. (2017): 6.60 and 6.72 g/kg $BW^{0.75}$ or 0.65 and 0.64 respectively.

Table 2. Calibration and validation performances (outdoor measures) for faecal NIRS calibration equations developed from faeces samples of sheep

	Calibration set					Validation set		
Parameter	**N**	**SEC**	**R^2cal**	**SECV**	**R^2cv**	**N**	**SEP**	**R^2val**
DMI (g/kg $BW^{0.75}$)	622	6.52	0.81	6.86	0.79	36	8.38	0.01
OMI (g/kg $BW^{0.75}$)	615	5.17	0.86	6.21	0.80	36	8.20	0.09
DMD (%)	236	1.50	0.93	2.01	0.88	36	3.71	0.76
OMD (%)	104	1.95	0.88	2.41	0.82	21	2.26	0.82

N: number of observations; SEC: standard error of calibration; R^2cal: coefficient of determination of calibration; SECV: standard error of cross-validation; R^2cv: coefficient of determination of cross-validation; SEP: standard error of prediction; R^2val: coefficient of determination of validation; DMI: dry matter intake; OMI: organic matter intake; DMD: *in vivo* dry matter digestibility; OMD: *in vivo* organic matter digestibility.

For OMI the SEC (5.17 g/kg $BW^{0.75}$) and R^2cal (0.86) were similar to those reported by Decruyenaere *et al.* (2009) with values ranging from 3.46 to 5.15 g/kg $BW^{0.75}$ for SEC and 0.66 to 0.89 for R^2cal for sheep. These values were also in agreement with those reported by Boval *et al*. (2004) on cattle with values ranging from 3.40 to 9.60 g/kg $BW^{0.75}$ for SEC and 0.61 to 0.90 for R^2cal.

The calibration statistics obtained for DMD and OMD (SEC=1.50%; R^2cal=0.93 and SEC=1.95%; R^2cal=0.88 respectively) were consistent with the values reported by Dixon and Coates (2009). The values of SEC ranged from 1.70% to 3.20% for DMD and from 1.50% to 3.20% for OMD and the values of R^2cal reported ranged from 0.91 to 0.98 for DMD and 0.80 to 0.94 for OMD.

The results of the validation show that it is possible to extrapolate the prediction of digestibility of grazing animals using calibrations established with indoor trials. However, these results need to be confirmed with more outdoor trials samples. On the other hand, this extrapolation was not possible for DMI or OMI (SEP higher than SEC or SECV and very low R^2val). This result is certainly due to the low number of outdoors samples obtained on natural rangeland including hundred species.

IV – Conclusions

The results of this study confirm that our database aggregating 20 years of collect of faeces sample's during animal trials on sheep could contribute to support the management of small ruminants. However, in order to improve the robustness of these calibrations, future work will need to implement the database with more variability in term of diet and field conditions.

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Effects of pasture type on tissue composition and sensorial meat quality of lambs raised under the organic livestock system

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Abstract. In organic livestock system, animals should have access to pasture. This study aims to determine the effects of the pasture type (PT) used to fattened lambs according to organic conditions. Fifty four Barbarine lambs with an initial average weight of 24.06±5.01 kg and 8 month-old were divided into two homogeneous groups. Each group received 200 g of organic oat hay and 400 g of organic farmer concentrate (63.7% barley, 18.2% broad bean, 13.6% faba bean, 4.5% mineral vitamin supplement) with access either to natural pasture (NP) or a cultivated green barley pasture (BP) both organic certified. Six lambs from each group were slaughtered at an average weight of 35 kg. Results obtained indicated that NP lambs had higher lean proportions in leg (+3.13%) and lumbar region (+5.88%) than those reread on BP, but no effects of PT were found for fat proportions (P>0.05). As for instrumental meat color parameters, redness (a*) were higher on NP lambs *Longissimus lumborum* (LL) and *Semitendinosus* (ST) muscles. Yellowness (b*) was not affected by PT for both muscles (P>0.05). The meat sensory quality was slightly affected by PT. ST muscle of NP lambs was more tender (7.15 *vs* 5.51; P<0.001) than those produced on BP. Feeding lambs on NP tended to increase meat juiciness and flavor (P < 0.10). However, fat degree was higher in LL muscle of BP lambs (P<0.05). Green barley pasture can be used as an alternative feed resource to fed lambs according to organic system especially in the drought season.

Keywords. Organic livestock system – Pasture type – Tissue composition – Lamb – Sensorial meat quality.

Effets du type de parcours sur la composition tissulaire et la qualité sensorielle de la viande d'agneaux élevés en mode de production biologique

Résumé. *Dans le système de l'élevage en mode biologique, les animaux doivent avoir accès au pâturage. Cette étude vise à déterminer les effets du type de parcours (PT) utilisé pour engraisser les agneaux selon les conditions de l'élevage en mode biologique. Cinquante-quatre agneaux de race Barbarine ayant un poids moyen initial de 24,06±5,01 kg et âgés de 8 mois ont été divisés en deux groupes homogènes. Chaque groupe a reçu 200 g de foin d'avoine biologique et 400 g de concentré (63,7%, orge, 18,2% fève, 13,6 % féverole, 4,5% CMV)avec un accès soit à un parcours naturel (NP) ou à une prairie d'orge cultivée en vert (BP) tous deux certifiés biologiques. Six agneaux de chaque groupe ont été abattus à un poids moyen de 35 kg. Les résultats obtenus indiquent que les agneaux du groupe NP présentent des proportions plus élevées en muscle pour la cuisse (+3,13%) et la région lombaire (+ 5,88%) que ceux élevés sur BP, alors qu'aucun effet de PT n'a été trouvé pour les proportions du gras (P> 0,05). En ce qui concerne les paramètres de couleur de la viande, l'indice de rouge (a *) était plus élevé dans les* muscles Longissimus lumborum *(LL) et* Semitendinosus *(ST) des agneaux NP. L'indice de jaune (b *) n'a pas été affecté par le PT pour les deux muscles (P> 0,05). La qualité sensorielle de la viande était légèrement affectée par le PT. Le muscle ST des agneaux NP est plus tendre (7,15* vs *5,51; p <0,001) par rapport à celui des agneaux élevés sur BP. La conduite des agneaux sur NP tend à augmenter la jutosité et la flaveur de la viande (P <0,10). Cependant, le degré de gras a été plus élevé dans le muscle LL des agneaux BP (P <0,05). Le pâturage en vert sur une prairie d'orge cultivée pourrait être utilisé comme une ressource alimentaire alternative pour engraisser les agneaux selon le mode de production biologique, en particulier pendant la saison de sécheresse.*

Mots-clés. *Système d'élevage biologique – Type de parcours – Composition tissulaire – Agneaux – Qualité sensorielle.*

I – Introduction

In the last decades, following crises that have affected the image of the meat quality such as mad cow and bird flu (Kouba, 2003), consumer has become increasingly demanding in terms of the knowledge of the origin and the production systems of meat products. Thus, the choice is oriented more towards production methods with fewer inputs and chemicals, in other words towards the natural or organic system. Thus, to meet these consumer demands, the quality of red meat had a new challenge (Galgano *et al*., 2016). However, meat produced on grass-fed system has a good nutritional quality (Prache *et al*., 2011, Majdoub-Mathlouthi *et al*., 2015).The regulation of organic animal livestock requires mandatory access to pasture with supplementation of concentrate which must not exceed 40% DM of the ration (JORT, 2005).

In Tunisia, the production and quality of rangeland biomass depends on the climatic conditions which are difficult, especially in the semi-arid and arid regions of the country. The yield of pasture biomass remained low because of the degraded state of rangelands caused by drought and overgrazing (Ben Salem, 2010). Then, it was necessary to find another alternative to guarantee the access to pasture for animals raised under organic livestock system, when conditions do not permit. Barley among cereals seems to provide a solution to a livestock-based production system, as it can be an excellent source of animal feed. It is used in its various forms (grain, forage, straw). This work aims to compare the effect of two pasture types (natural pasture vs. green barley) on tissue composition and sensory meat quality of lamb reared under organic system.

II – Materials and methods

This study was carried out at the Farm of Office des Terres Domaniales (OTD) El Attizez (Sidi Bouzid, Tunisia). All procedures of organic livestock farming practiced in this study (feeding, health, transport and slaughtering) meet the Tunisian legislation law number 2005–57 of organic livestock system (JORT, 2005). Fifty four 8 month-old Barbarine lambs of an average body weight of 24.06±5.01 kg were divided into two homogenous groups (27 lambs per group : 11 females and 16 males) : according to initial body weight and sex, the first group reared under certified organic natural pasture (NP) and the second group on cultivated green barley (*Hordeum vulgare*) pasture (BP). Each group received 200 g of organic oat hay and 400 g of organic farmer concentrate (63.7% barley, 18.2% broad bean, 13.6% faba bean, 4.5% mineral vitamin supplement). Chemical composition of experimental feeds used in this study is shown in Table 1.

Table 1. Chemical composition of experimental feeds (%DM)

	Oat hay	Natural pasture (NP)	Barley pasture (BP)	Concentrate
Dry matter (%)	90.68	45.97	33.5	93.69
Ash	7.22	12.19	9.05	5.50
Crude protein	3.63	10.69	7.28	14.81
NDF	67.85	65.36	62.26	31.66
ADF	37.09	39.43	33.54	7.23
ADL	4.96	5.19	3.78	2.18

DM: Dry matter; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; ADL: Acid detergent lignin.

At the end of the experimental trial which lasted 103 days, six lambs of each group were slaughtered at an average live weight of 35 kg after 16 h of fasting with free access to water. The carcasses were chilled at 4°C for 24 h after which was weighted (cold carcass weight), split along the midline and cut according the method of Fisher and De Boer (1994). Leg and lumbar region were removed from the left side, weighted and dissected to determine their tissue composition. The *Longissimus lumborum*(LL) and *Semitendinosus* (ST) muscles were removed from both sides.

Lightness (L*), redness (a*) and yellowness (b*) color parameters of LL and ST muscles were measured using a Minolta CR-401 chromameter (Osaka, Japan) according to the CIE system (1986). Sensory meat quality of LL and ST muscles were assessed by a taste panel. LL and ST muscles samples were cooked in a preheated oven of 240°C until the core temperature reached 70 °C. Immediately after cooking, muscle was divided in 1.5 × 1.5 cm cubed samples and placed in aluminium foil. Ten tasters participated in this sensory meat evaluation to asses color (0 = very clear, 10 = very dark), tenderness (0 = extremely tough, 10 = extremely tender), juiciness (0 = extremely dry, 10 = extremely juicy), flavour (0 = very low, 10 = very intense), degree of fatty (0 = very lean, 10 = high fat) and acceptability (0 = not acceptable, 10 = extremely acceptable). Bread and water were provided for panellists to refresh their palates between samples.

The data were analyzed by the GLM procedure of the STATISTICA (version 5.5, Stat Soft, Tulsa, Ok, USA). The model included pasture type as a fixed factor and the slaughter weight was used as covariate for analyses of carcass traits and meat quality. The differences between the means were compared by the Duncan test and considered significant when $P \leq 0.05$.

III – Results and discussion

The results of weight and yield carcass and proportions and tissue composition of leg and lumbar region are varied with the pasture type (PT) (Table 2). NP lambs had greater commercial dressing percentage. PT had affected ($P<0.05$) the proportions of leg and lumbar region. Feeding lambs under BP had increased the proportions of leg and lumbar region respectively by +1.40% and +0.72% compared with feeding under BP. For both groups, the average proportions of leg and lumbar region were respectively 33.96%and 7.83% of the total carcass weight. These values were similar to those reported by Karim *et al*. (2007). Regarding the tissue composition of leg and lumbar region, lean proportions in leg and lumbar region were higher respectively by +3.13% and +5.88% for the NP lambs compared with those of BP group. The bone of leg was significantly more developed for the BP lambs. However, the pasture type did not affect ($P>0.05$) fat proportions for both leg and lumbar region. Our results were different to those reported by Mekki *et al*. (2014) who found that the percentage of lean in carcass did not change between lambs reared under herbaceous or woody pastures.

Table 2. Effects of pasture types on carcass traits, proportions (% untailed carcass) and tissue composition of leg and lumbar region (%) of Barbarine lamb

		Natural pasture (NP)	Barley pasture (BP)	SEM	Effect
Weights and yield carcass	Initial weight (kg)	24.11 ± 5.41	24.06 ± 5.01	–	–
	Final weight (kg)	30.35 ± 6.55	31,26 ± 6,42	–	–
	Slaughter weight (kg)	36.90	34.00	0.773	*
	Cold carcass weight (kg)	16.57	16.45	0.174	NS
	Commercial dressing (%)	46.72	46.35	0.729	**
Proportions (%)	Leg	33.26	34.66	0.783	**
	Lumbar region	7.47	8.19	0.342	*
Tissue composition (%)	Leg				
	Lean	69.48	66.35	1.179	***
	Fat	10.48	12.80	1.316	NS
	Bone	18.13	18.38	0.440	***
	Lumbar region				
	Lean	65.72	59.84	1.586	***
	Fat	15.68	18.96	3.030	NS
	Bone	17.21	16.74	1.479	NS

Results of color and sensory quality of meat are shown in Table 3. For both muscles, redness (a*) values were higher in NP lambs than in those reared on BP. This result indicated probably a higher physical activity exercised by lambs reared under NP. Feeding lambs under NP had increased lightness (L*) in LL muscle. These findings indicated that LL muscle of NP lambs is lighter and has a more intense redness. However, pasture type did not affect (P>0.05) yellowness values for both muscles. The meat sensory quality was slightly affected by PT. In fact, for the LL muscle panellists reported no significant effect of PT on the eating quality of lamb meat except the degree of fatty which was higher in LL muscle of BP lambs (P<0.05).The similarity in tenderness and juiciness could have resulted from the similarity of the carcass fatness. Also, panellists found that ST muscle of NP lambs was only more tender (7.15 vs. 5.51; P < 0.001) than those produced on BP. Meat juiciness and flavor in ST muscle tended (P=0.062 and P=0.095, respectively) to increase with feeding lambs on NP that could be related to the floristic composition of NP. In fact, Prache *et al*. (2011) reported that meat flavor vary mainly with the presence of legumes species in pastures.

Table 3. Effects of pasture type on Barbarine lamb meat color and sensory quality of *Longissimus lumborum* and *Semitendinosus* muscles

			Natural pasture (NP)	Barley pasture (BP)	SEM	Effect
Color	*Longissimus lumborum*	L	38.24	36.71	0.717	***
		a*	21.20	20.23	0.438	***
		b*	4.15	3.05	0.338	NS
	Semitendinosus	L	46.88	48.37	1.735	NS
		a*	21.90	19.31	0.219	*
		b	5.48	4.29	0.339	NS
Sensory quality	*Longissimus lumborum*	Color	5.11	4.73	0.348	NS
		Tenderness	6.49	6.74	0.325	NS
		Juiciness	5.74	6.33	0.377	NS
		Flavour	5.26	5.52	0.343	NS
		Degree of fatty	4.29	5.58	0.340	*
		Acceptability	5.46	5.96	0.399	NS
	Semitendinosus	Color	4.27	4.94	0.343	NS
		Tenderness	7.15	5.51	0.289	***
		Juiciness	5.94	5.12	0.282	<0.1
		Flavour	5.55	5.31	0.229	<0.1
		Degree of fatty	4.83	4.59	0.319	NS
		Acceptability	6.16	5.53	0.284	NS

IV – Conclusions

Feeding lambs on natural pasture produced leaner leg and lumbar region.As for the sensorial properties, ST muscle was more tender and meat juiciness and flavour tend to increase with feeding lambs on natural pasture. Green barley pasture can be used as an alternative feed resource to fed lambs according to organic system especially in the drought season.

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Protein conversion efficiency in French dairy small ruminant systems

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Abstract. Dairy production is facing social issues due to competition in the use of resources (feeds, water and land). The French livestock Institute (Idele) has characterized feed conversion efficiency for the dairy small ruminants in France. DIAPASON database from a reference farms' network (INOSYS-Réseaux d'élevage) has been used to determine the efficiency of a large number of dairy systems in France between 2012 and 2016. Systems studied in this reference network are on average net producers of proteins: 52% for dairy sheep and almost 50% for dairy goats. Diet composition is of critical importance. Cereals are directly in competition with human nutrition while grass as pasture or silage are not, giving a positive impact on efficiency. This is why we show that grass-based dairy systems, specifically those with pasture, are very efficient to turn proteins from grass into high-quality proteins for human nutrition. A high variability within and between systems and species is shown and gives the opportunity to propose technical ways to improve this new approach on farm.

Keywords. Dairy systems – Feed conversion efficiency – Goat – Sheep – Competition feed/food.

L'efficience de conversion des protéines dans les systèmes français de petits ruminants laitiers

Résumé. *L'élevage et la production d'animaux laitiers font face aujourd'hui à des problèmes de société dus à la compétition dans l'utilisation des ressources (alimentation des animaux, eau et utilisation des terres). L'Institut de l'Elevage (Idele) a caractérisé l'effcience de conversion alimentaire des élevages de petits ruminants laitiers, les brebis et les chèvres laitières. La base de données DIAPASON, issue de la collecte dans un réseau de fermes de référence (Inosys-Réseaux d'élevage), a été utilisée pour déterminer l'efficience d'un grand nombre de systèmes laitiers français entre 2012 et 2016. Les systèmes étudiés dans ce réseau de référence sont en moyenne producteurs nets de protéines : 52% pour les ovins laitiers et quasiment 50% pour les chèvres laitières. La composition de la ration a une importance cruciale. Les céréales sont directement en compétition avec l'alimentation humaine tandis que l'herbe, en pâturage, foin ou ensilage, ne l'est pas et a donc un impact positif sur l'efficience. C'est pourquoi nous avons pu montrer que les systèmes laitiers basés sur l'herbe, en particulier ceux basés sur le pâturage, sont très efficaces pour convertir les protéines de l'herbe en des protéines de haute qualité pour la nutrition humaine. Une grande variabilité existe en intra– et en inter-systèmes, mais aussi entre les espèces, ce qui nous donne l'opportunité de proposer des voies techniques pour approfondir et améliorer l'utilisation cette nouvelle approche en élevage.*

Mots-clés. *Systèmes laitiers – Efficience de conversion alimentaire – Chèvres – Brebis – Niveau de compétition.*

I – Introduction

Dairy production is facing social issues due to competition in the use of resources (feeds, water and land). Ruminants are often characterized as non-efficient because they consume around 3 kg of plant proteins to produce 1 kg of milk (Peyraud and Peeters, 2016). But the truth is more nuanced. This approach does not take into account that ruminants (i) have the ability to value non-human edible resources such as grass and by-products, (ii) release high quality products with high nutritional values. In addition, animal husbandry has positive externalities beyond food production, like landscape and biodiversity conservation or storage of carbon (Hoffmann *et al.*, 2014). So a new approach has been proposed dealing with the evaluation of human-edible from human non-edi-

ble feedstuffs in livestock feeding strategies. Some results using this new criteria are already available in the literature for different feeding systems in different countries (Wilkinson, 2011; Ertl *et al*., 2015). The objective of our study is to determine the conversion efficiency –for both energy and proteins– of a large number of dairy systems in France for goat and sheep production.

II – Materials and methods

1. Data collection

DIAPASON database from a reference farms' network (INOSYS-Réseaux d'élevage) has been used for a large number of dairy systems in France between 2012 and 2016. This network lasts since more than 30 years and allows the collection of various and numerous data routinely on more than 1,000 farms. The total intake for both roughages and concentrates has been registered: inventory changes for all feeds except for pasture (estimation). The total meat and milk production has also been collected. Over the 5 years of the database used for this study, missing and uncoherent data have been deleted leading to 847 data from 274 farms for dairy goats and 343 data from 108 farms for dairy ewes.

The first step has been to use and complete an existing table of human-edible energy and protein fractions of the main feedstuffs used in France (Laisse *et al*., 2016). For example, the human-edible protein fraction is 66% for wheat whereas it is 0% for rapeseed or sunflower meals. For roughages, this fraction is estimated to 0%, except for maize silage (10%) to consider the grain fraction. Almost a hundred of feeds have been characterised, as shown in Table 1 (few examples).

Table 1. Proportion of human-edible protein in some feeds from dairy ruminants' ration

Type of feed	Feed	Proportion of human-edible protein (%)
Forage	Pasture	0
Forage	Maize silage	10
Forage	Hay	0
Forage	Non mature cereals silage	70
Concentrate	Wheat	66
Concentrate	Faba bean	92
Concentrate	Soybean meal	60
Concentrate	Canola meal	0
Concentrate	Industrial concentrate (22% protein)	46
Concentrate	Beet pulp	0

2. Calculation

The second step is the calculation of 2 ratios to estimate the efficiency for protein (kg of crude protein/kg of feed and animal products). The total efficiency considers the ratio between the total outputs (meat and milk production) and inputs (feedstuffs intake) while the net efficiency considers only human-edible fractions of inputs. All calculations are made at the farm level, including both intake and production for all types of animals (young and adults for meat and milk).

III – Results

1. Part of proteins consumed by goats (G) and sheep (S) that are not consumable by humans

Food systems in goat farming are defined within the framework of the Observatory of the feeding of dairy goats (Bossis and Jost, 2016): 9 feed systems are defined, according to the nature and the quantity of the fodder used in the ration of the goats. In France, fodder constitutes on average 68% of the goats' diet. The grass, green or preserved, represents 65% of the goats' ration and hay is present in the ration of almost all the goats (50% of the ration). This share varies according to the region, depending on climatic conditions and soil potential. Concentrates make up an average of 32% of goats' diet. They are produced on average at 23% on the farm. The average annual consumption of goat herd concentrates in France is 383 kg DM per goat: 43% of the food is raw seeds (cereals and oil-protein crops), 39% are compound feeds with high levels of competition and 13% of concentrated feeds are by-products with low levels of competition.

Food systems in sheep farming are defined within the framework of the Observatory Inosys-Réseaux délevage. We only consider in this study farms that are delivering milk (i.e not on-farm cheese producers). Within those farms, 11 systems are defined but to make it more simple, 5 groups have been defined, depending only on geographical area and practice of transhumance. In France, sheep feeding is mainly based on conditions to obtain the PDO labels. For forages, to produce Roquefort ewes have to receive 1 kg DM of hay per day and grazing is mandatory every day when meteorological conditions are good enough. To produce Ossau-Iraty, ewes have to graze 240 days minimum per campaign and silage is forbidden during milking period. For concentrates, it is limited to 800 g per day and per ewe for the Ossau-Iraty PDO.

On average, 83% (G) and 88% (S) of the proteins consumed by goats and sheep cannot be consumed by humans. Only 17% (G) and 12% (S) of proteins are human-edible food.

2. Part of goat and sheep farms that are net producers of protein for human consumption

Almost 50% of goat farms and 52% of sheep farms are net producers of protein for human consumption.

Total protein efficiencies are on average 0.15 (G) and 0.13 (S). This indicator is not very variable between feed systems (Table 2), in relation with the share of fodder (G+S) and the level of milk production (G). It takes 6.7 kg (G) and 7.7 kg (S) of vegetable protein to produce 1 kg of animal protein.

The net efficiencies for protein are 1.14 (G) and 1.16 (S). Goat and sheep sectors are therefore on average net producer of proteins for human consumption. For both productions, it then takes 0.9 kg of protein from vegetables that could be eaten by humans to produce 1 kg of animal protein.

The mean values, however, hide a variability within the sample, with high net efficiencies for protein standard deviation of 0.86 (G) and 0.55 (S). Only 43% of goat farms and 52% of sheep farms are net producers of protein for human consumption. Nevertheless, the margins of manoeuvre exist since 65% (G) and 71% (S) of farms have a net protein efficiency level higher than 0.8. This means that 20% of French goat and sheep farms are close to equilibrium (net efficiciency value = 1).

Table 2. Total and net protein utilisation of food resources for some dairy goat and sheep systems

Feed system (G: goat, S: sheep)	Part of protein consumed by animals that can not be consumed by humans (%)	Total protein efficiency	Net protein efficiency	Part of the system at the national level (%)
Average (G) n=847	**83**	**0.15**	**1.14**	
Pastoral (G) n=191	88	0.13	1.54	20
Legumes hay (G) n=135	81	0.16	0.93	19
Pasture (G) n=208	85	0.15	1.08	18
Maize silage (G) n=81	79	0.18	0.74	10
Average (S) n=343	**88**	**0.13**	**1.16**	
Corsica (S) n=33	92	0.10	1.38	7.7
Pyrénées-Atlantiques, transhumant (S) n=54	91	0.10	1.28	34.7
Roquefort area, pastoral (S) n=84	88	0.14	1.02	24.3

Source: DIAPASON.

IV – Conclusion

Protein feed conversion efficiency is a critical issue for the future for ruminant production, as it is part of the competition between feed and food uses. For the future, more issues have to be addressed on this database like land use ratio to estimate land use efficiency of livestock systems (van Zanten *et al*., 2016) and animal protein quality for human nutrition. Energy feed conversion efficiency will also be studied. Another step of this project deals with a better understanding of the variability of these indicators, with technical factors. The variations in net efficiency can be explained mainly by (i) the level of grass in the diet, (ii) the ratio between milk production and the amount of concentrates and (iii) forage quality.

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Effect of the drying process of sainfoin on *in vitro* fermentation parameters

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Abstract. Sainfoin (*Onobrychis viciifolia)* is an interesting legume due to its high production and its content of condensed tannins, which reduce methane production in the rumen. It is advisable to preserve this forage to optimize its use for animal feeding because two thirds of the annual production are obtained in the first spring cut. The objective of the present study was to evaluate the effects of different drying processes on the chemical composition and the *in vitro* fermentation parameters. Sainfoin was collected at the early flowering stage and was dried under the following conditions: freeze-dried, sun-dried and dried at 40, 60 and 80 ºC in an air-forced oven. After 24 h of incubation, contents of ammonia and volatile fatty acids were determined and *in vitro* organic matter degradability (IVOMD) was estimated. Freeze-dried sainfoin presented the lowest content of crude protein and fibres (neutral and acid detergent fibres) and the greatest condensed tannins (CT) content ($P<0.05$). In contrast, the 80ºC-oven dried sainfoin presented the highest fibre contents and the lowest CT content. Regarding the *in vitro* fermentation, the drying method had not effect on most of the assessed parameters, except for IVOMD ($P<0.001$), showing the lowest value the sun-dried sainfoin. In conclusion, the different drying conditions affected the chemical composition, but they had minor effect on the *in vitro* fermentation.

Keywords. Condensed tannins – IVOMD – Gas production – Methane production.

***Effet des conditions de séchage du sainfoin sur les paramètres de fermentation* in vitro**

Résumé. *Le sainfoin (*Onobrychis viciifolia*) est une légumineuse intéressante par son potentiel de rendement at par son contenu en tannins condensés, qui réduisent la production de méthane ruminale. Il est conseillé de conserver ce fourrage pour optimiser son utilisation en alimentation animale car les deux tiers de la production annuelle sont obtenus lors de la première coupe du printemps. L'objectif de la présente étude était d'évaluer les effets de différents processus de séchage sur la composition chimique et les paramètres de fermentation in vitro. Le sainfoin a été récolté au début de la phase de floraison et a été séché dans les conditions suivantes: lyophilisé, séché au soleil et séché à 40, 60 et 80 ºC dans un four à air forcé. Après 24 h d'incubation, les teneurs en ammoniac et en acides gras volatils ont été déterminées et la dégradation de la matière organique in vitro (IVOMD) a été estimée. Le sainfoin lyophilisé présentait la plus faible teneur en protéines brutes et en fibres (fibres au détergent neutre et acide) et la plus grande teneur en tanins condensés (CT) ($P<0,05$). En revanche, le sainfoin séché au four à 80 ºC présentait les teneurs en fibres les plus élevées et les teneurs en CT les plus faibles. Concernant la fermentation in vitro, la méthode de séchage n'a pas eu d'effet sur la plupart des paramètres évalués, à l'exception de l'IVOMD ($P<0,001$), indiquant la valeur la plus faible du sainfoin séché au soleil. En conclusion, les différentes conditions de séchage ont affecté la composition chimique, mais ont eu un moins d'effet sur la fermentation in vitro.*

Mots-clés. *Tanins condensé – IVOMD – Production de gaz – Production de méthane.*

I – Introduction

The interest in sainfoin (*Onobrychis viciifolia),* a perennial legume extensively used in the Mediterranean area, has increased due to its content of condensed tannins (CT; 50-80 g/kg DM), which reduce methane production in the rumen (Hatew *et al*., 2016). It is advisable to preserve the sainfoin

to optimize their use for animal feeding because two-thirds of the annual production of these forages are obtained in the first spring cut. Preservation can increase the fibrous fraction, reduce the crude protein (CP) and change the fractions of CT (Wang *et al*., 2015). Nevertheless, the extent of the effects is dependent on the method of preservation, silage or hay, and the legume species (Rufino-Moya *et al*., 2019). To the best of our knowledge, the effects of haymaking on ruminal fermentation have been scarcely studied in sainfoin and differed on the drying conditions (Scharenberg *et al*., 2007; Wang *et al*., 2015). The objective of the present study was to evaluate the effects of different controlled drying conditions on the chemical composition and the *in vitro* fermentation parameters of sainfoin, in order to assess how these conditions can affect to the nutritional value of this forage.

II – Materials and methods

Samples of sainfoin were collected at the early flowering stage. Fifty samples were obtained from 0.25 m^2 areas randomly allocated in the plot. The samples were randomly assigned to one of five treatments. The 10 samples of each treatment were mixed homogenously into 1 sample, and then divided into three sub-samples, to have three repetitions. The five treatments were: freeze-dried, sun-dried and dried at 40, 60 and 80 ºC in an air-forced oven. The sub-samples for the sun-dried treatment were extended on 10-cm elevated "mosquito" nets for 16 days, that were kept outdoors except during the night or when it rained. After the drying process, samples were ground to pass 1 mm screen (Rotary Mill, ZM200 Retsch, Germany) and used to determine ash and fibre fractions. One part of the sample was ground to pass a 0.2 mm screen and used to determine CP and CT content. Chemical analyses are described in Rufino-Moya *et al*. (2019). Briefly, the dry matter (DM), ash and crude protein (CP) contents were determined according to the AOAC methods (AOAC, 2000). Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (lignin)) contents were determined according to the method described by Van Soest *et al*. (1991). Condensed tannins content was determined with the colorimetric HCl-butanol method described by Grabber *et al.* (2013), using the cyanidin as standard.

All the procedures used in the experiment were carried out in accordance with the Spanish guidelines for experimental animal protection (RD 53/2013) with the approval of the Institutional Animal Care and Use Committee of the Research Centre (Procedure number 2011-05). Four Rasa Aragonesa wethers (65 ± 2.1 kg body weight) fitted with rumen cannula were used as donors of ruminal contents. The animals were housed in individual pens (150 cm x 150 cm) with free access to water and a mineral-vitamin mixture. Wethers were fed 70% alfalfa hay and 30% barley grain. The rumen digesta was strained through 4 layers of cheesecloth and the fluid was mixed with the buffer solution, based on the protocol of Menke and Steingass (1988). Three 0.5 g DM sub-samples of each diet were incubated in bottles with 60 ml of incubation solution in a water bath (39 ºC) for 24 h, in three runs on three separate days. Blanks were included in each run and gas production was corrected with the blanks. After this period, 8 ml of gas were collected in 5 ml vacutainer tubes to quantify methane production. Then, the fermentation was stopped placing the bottles for 5-10 minutes in ice and the pH was measured immediately with a microPH 2002 (Crison Instruments S.A., Barcelona, Spain). To determine the ammonia (NH_3-N) content, 2.5 mL of liquid was mixed with HCl 0.1 N in a proportion of 1:1 (v/v). For volatile fatty acid (VFA) determination, 0.5 mL of liquid was added to 0.5 mL of deproteinising solution (5 mL of 85% (v/v) ortho-phosphoric acid and 0.125 mL of 4-methylvaleric acid (Sigma Aldrich, St.Louis, MO, USA) as internal standard, dissolved in 250 mL of distilled water) and 1 ml of distilled water. Tubes with samples of VFAs were stored at –20 °C until future analyses. Methane was analysed with gas chromatograph HP-4890, equipped with a capillary column TG-BOND Q+ (Thermo Scientific). Methane identification was based on the retention time as compared with the standard. *In vitro* organic matter digestibility (IVOMD) was estimated by filtering residues using pre-weighed bag (50 ! m; Ankom, NY, USA). The bags with sample were dried at 103 ºC for 48 h to obtain the dry matter content. After 48 h, bag content was weighed and

was placed at 550 ºC for to obtain the ashes. The organic matter of bag content was obtained as DM-ashes and the IVOMD was obtained as: (Incubated OM-bag content OM)/Incubated OM.

Data were analysed with a general lineal model with the forage conservation as fixed effect. Differences were significant for P<0.05 and tendencies for P<0.10.

III – Results and discussion

The drying method affected all the parameters of the chemical composition (Table 1). Freeze-dried sainfoin presented the lowest content of crude protein and fibres (neutral and acid detergent fibres) and the greatest CT content (P<0.05). In contrast, the 80 ºC-oven dried sainfoin presented the highest fibre contents and the lowest CT content. The greatest NDF content of 80ºC-oven dried sainfoin could be ascribed to an effect of temperature. Lignin also increased with the temperature whereas CT decreased. The presence of CTs led to an overestimation of the lignin content using conventional gravimetric methods such as the ADL (Marles *et al*., 2008). Limited information is available about the persistence of CT-effects after the forages have been conserved. The artificial drying using high temperatures (65 ºC) can decrease the chemical activity of CT (Scharenberg *et al*., 2007). As in the present study, the hay had greater fibre contents than the fresh forage (Rufino-Moya *et al*., 2019), however, the CP total CT contents were not affected.

Table 1. Chemical composition of the sainfoin hay according to the drying process

			Air forced oven				
% Dry matter	**Freeze-dried**	**Sundried**	**40ºC**	**60ºC**	**80ºC**	**S.E.**	**[1]P-value**
Organic matter, %	91.7^{a}	91.3^{c}	91.2^{d}	91.3^{cd}	91.5^{b}	0.03	0.001
Crude protein, %	17.1^{b}	18.3^{a}	18.8^{a}	18.7^{a}	18.1^{ab}	0.30	0.04
Neutral detergent fibre, %	45.3^{c}	47.3^{b}	47.4^{b}	47.9^{b}	51.0^{a}	0.60	0.001
Acid detergent fibre, %	31.5^{d}	33.6^{c}	34.5^{b}	33.9^{bc}	36.1^{a}	0.23	0.001
Acid detergent lignin, %	8.6^{d}	10.1^{c}	11.9^{ab}	10.9^{bc}	12.7^{a}	0.47	0.001
Condensed Tannins[2]	29.4^{a}	14.6^{b}	10.6^{cd}	12.9^{bc}	8.9^{d}	1.14	0.001

[1] Standard error. [2] Expressed as g of equivalent of cyanidine/kg DM.

Regarding the *in vitro* fermentation, the drying process had not effect on most of the parameters studied, except for pH and IVOMD (P<0.001, Table 2). Although differences were observed in the pH, they ranged into the optimal fermentation conditions (6.5-6.8; Amanzougarene *et al.,* 2017*).* The gas and methane production was numerically greater in freeze-dried sainfoin, but not significantly, whereas the rest of the drying methods presented similar productions (Table 2). The sundried sainfoin presented the lowest IVOMD whereas the freeze-dried sainfoin presented the greatest value (P<0.05), reflecting that CT and fibre contents determine the degradability. Ammonia, total VFA production and the ratio C_2:C_3 were similar among treatments (P>0.05, Table 2).

IV – Conclusions

In conclusion, the different drying conditions affected the chemical composition, but had minor effect on the *in vitro* fermentation of sainfoin. Studies of the CT fractions and composition should be carried out to unmask the importance of CT on the ruminal fermentation.

Table 2. Effect of the drying process of sainfoin on the in vitro fermentation parameters after 24 h of incubation

Parameters	Freeze-dried	Sundried	Air forced oven			S.E.	P-value
			40ºC	60ºC	80ºC		
pH	6.58[c]	6.68[b]	6.75[a]	6.7[ab]	6.71[ab]	0.04	<.0001
Gas production (mL/g MO)	170	144	149	144	149	17.86	0.13
CH4 production (mL/g MO)	5.84	4.29	5.10	4.83	4.63	1.36	0.46
IVOMD	71.8[a]	62.9[c]	68.6[b]	68.7[b]	70.1[ab]	2.34	<.0001
NH_3-N (mg/L)	114	123	128	122	115	27.21	0.91
Total VFA (mmol/L)	57.02	55.87	59.04	56.36	55.82	4.73	0.81
Acetic acid, %	65.9	66.0	65.4	65.8	66.1	0.69	0.47
Propionic acid, %	15.3	15.3	15.1	15.1	15.1	0.56	0.96
Butyric acid, %	12.7	12.7	13.0	12.9	12.8	0.87	0.97
Iso-butyric acid, %	1.6	1.5	1.7	1.5	1.5	0.14	0.37
Valeric acid, %	1.6	1.6	1.7	1.6	1.6	0.11	0.42
Iso-valeric, %	2.5	2.5	2.7	2.5	2.5	0.20	0.23
Acetic: Propionic	4.32	4.34	4.33	4.36	4.38	0.17	0.98

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Effect of the rate of inclusion of field pea in the concentrate of lambs on *in vitro* fermentation parameters

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Abstract. The replacement of soya by local protein sources, as the field pea (*Pisum sativum*), has been encouraged to reduce the dependency of Europe on soya imports. The aim of this study was to investigate the effect of increasing amounts of field pea in the lamb's concentrate (0%Pea, 10%Pea, 20%Pea and 30%Pea) on *in vitro* fermentation. Gas production was determined with the Ankom system for 24 hours and the parameters of kinetics of fermentation were estimated. Methane, ammonia (NH_3-N) and *in vitro* organic matter degradability (IVOMD) were determined. Most of the parameters were affected by the rate of inclusion of pea. The 10%Pea concentrate had the lowest gas production and the NH_3-N content ($P<0.05$). Methane production was lower in 10%Pea than in 30%Pea ($P<0.05$), presenting 0%Pea and 20%Pea intermediate values. Regarding the IVOMD, the 10%Pea had greater degradability than 20%Pea and 30%Pea ($P<0.05$) presenting 0%Pea intermediate value ($P>0.05$). In conclusion, a partial substitution of soya by 10% field pea in lamb's concentrate could be recommended because it reduced gas and methane production and NH_3-N content whereas it increased IVOMD.

Keywords. Pea – Degradability *in vitro* – Ovine – Methane – Ammonia.

***Effet du taux d'inclusion de pois de grande culture dans le concentré d'agneaux sur les paramètres de fermentation* in vitro**

Résumé. *Le remplacement du soja par des sources de protéines locales, comme le pois de grande culture (Pisum sativum), a été encouragé afin de réduire la dépendance de l'Europe vis-à-vis des importations de soja. Le but de cette étude était d'étudier l'effet de l'augmentation des quantités de pois (0%de Pois, 10% de Pois, 20% de Pois et 30% de Pois) dans le concentré d'agneau sur la fermentation in vitro. La production de gaz a été déterminée avec le système Ankom pendant 24 heures et les paramètres de cinétique de fermentation ont été estimés. Le méthane, l'ammoniac (NH_3-N) et la dégradation de la matière organique in vitro (IVOMD) ont été déterminés. Le taux d'inclusion du pois a eu un effet sur la plupart des paramètres. Ainsi, le concentré de 10% de Pois a réduit la production de gaz et la teneur en NH_3-N par rapport au reste des concentrés ($p<0,05$). La production de méthane était plus faible pour le concentré de 10% de Pois que chez celui de 30% de Pois ($P<0,05$). Concernant l'IVOMD, le concentré de 10% de Pois avait une digestibilité supérieure à ceux de 20% et de30% de Pois ($p<0,05$) et similaire à celui de l'0% de Pois ($p> 0,05$). En conclusion, une substitution partielle du soja par 10% de Pois dans les concentrés d'agneau pourrait être recommandée car elle réduit la production de gaz, demethane et la teneur en NH_3-N, alors qu'elle augmenterait l'IVOMD.*

Mots-clés. *Pois – Dégradation* in vitro *– Ovine – Methane – Ammoniac.*

I – Introduction

In recent years, an important objective of European countries has been to reduce the use of soybean as protein source in animal diets, promoting the use of alternative protein sources, preferably from local feedstuffs. Most of the soybean is imported and it is genetically modified which causes rejection in part of the European consumers.

The substitution of soya by field pea (*Pisum sativum*), a local source of protein, in the fattening diets of lambs has been encouraged to reduce soya imports. Field pea is an interesting and promising legume crop in Mediterranean areas could potentially be rotated with cereal crops. It is characterized by having high crude protein (25-26% of dry matter), easily degradable in the rumen as all legume seeds (Goelema *et al*., 1998) and high levels of lysine and methionine (Saastamoin *et al.,* 2013). Pea also has high content of starch, with lower ruminal degradability than barley (Walhain *et al.,* 1992). There are few data available on the effects of feeding peas on degradability. Therefore, the aim of this study was to investigate the effect of increasing amounts of pea in the concentrate (0, 10, 20 and 30%) on *in vitro* fermentation parameters, through the *in vitro* gas production technique.

II – Materials and methods

Four concentrates for fattening lambs with different rate of inclusion of pea were evaluated in *in vitro* assay. The rate of inclusion of field pea was 0% (0%Pea), 10% (10%Pea), 20% (20%Pea) and 30% (30%Pea). All concentrates were formulated to be isoenergetic (1.18 MJ/kg FM) and isoproteic (175 g CP/kg FM).The ingredients and chemical composition are presented in Table 1.

Table 1. Main ingredients and chemical composition of the concentrates used in the trial

	Inclusion of field pea in the concentrates			
	0%	**10%**	**20%**	**30%**
Ingredients, %				
Barley	27.3	23	15.5	11.4
Corn	25.7	15	7.5	9.2
Soya meal	22.4	17.5	13	10
Common wheat	20	20	25	30
Pea 22/11	0	10	20	30
Bran	0	8.5	12.8	6.1
Cane molasses	1.5	1.5	1.5	0
Calcic carbonate	1.5	1.5	1.2	1.3
Palm oil	1	2.4	2.9	1.4
Salt and Vitamin	0.6	0.6	0.6	0.6
Chemical composition, g/kg DM				
Organic matter	948 ± 1	947 ± 1	949 ± 1	946 ± 2
Crude protein	199 ± 3	195 ± 4	196 ± 3	188 ± 3
Neutral detergent fibre	238 ± 41	246 ± 47	245 ± 35	252 ± 50
Acid detergent fibre	46.2 ± 2.9	54.8 ± 4.4	62.9 ± 3.7	61.4 ± 2.6
Acid detergent lignin	3.6 ± 2.0	5 ± 2.4	7.8 ± 2.2	5.6 ± 2.2

The analyses of *in vitro* gas production were carried out using the Ankom system (Ankom Technology, NY, USA). Rumen digesta collected from four rumen fistulated wethers, that were fed alfalfa hay:barley grain in a proportion of 70:30, was immediately strained through four layers of cheesecloth. Rumen fluid was mixed with the buffer solution, based on the protocol of Menke and Steingass (1988) in a proportion 1:2 (v/v) under constant CO_2 flux. Three runs were conducted on three separate days. In each run, three sub-samples (0.5 g DM) of each diet were incubated in bottles with 60 ml of incubation solution in a water bath at 39 ºC. Blanks were included in each run and gas production was corrected with the blanks. After 24h of incubation, the bottles were allocated on ice to stop the fermentation (5-10 minutes). Then were tempered at room temperature (10-15 minutes) and a sample of gas produced was transferred into vacutainer tube to determine CH_4 (Rufino-Moya *et al*., 2019). At the end of gas sampling, the pH was measured immediately

with a microPH 2002 (Crison Instruments S.A., Barcelona, Spain). For NH_3-N determination, 2.5 mL of liquid was mixed with 2.5 mL HCl 0.1 N and was determined in Epoch microplate Spectrophotometer (BioTek Instruments, Inc., Winooski, VT, USA) using the colorimetric method described by Chaney and Marbach (1992). The gas production recorded hourly for 24 h by the Ankom system was used to estimate the parameters of the kinetics of fermentation, adjusting the gas produced to the model described by France *et al*., (2000): $P= A*(1-e^{-ct})$, where P is the cumulative gas production (mL) at time t (h), *A* is the potential gas production (mL), and *c* is the rate of gas production (h^{-1}). Methane was analysed with gas chromatograph HP-4890, equipped with a capillary column TG-BOND Q+ (Thermo Scientific). Methane identification was based on the retention time as compared with the standard. *In vitro* organic degradability was estimated by filtering residues using pre-weighed bag (50 ! m; Ankom, NY, USA). The bags with sample were dried at 103 ºC for 48 h to obtain the dry matter content. After 48 h, bag content was weighed and was placed at 550 ºC for to obtain the ashes. The organic matter (OM) of bag content was obtained as DM-ashes and the IVOMD was obtained as: (Incubated OM-bag content OM)/Incubated OM.

Data were analyzed using statistical software SAS V.9.3 (SAS Inst. Inc., Cary, NC, USA). The fermentation kinetics parameters (*A* and *c*) were estimated through a non-linear regression model (Y=a + b*X) using SAS NLIN program. The pH, NH_3-N, total gas, methane, *A*, *c*, and IVOMD were tested by analyses of variance using the GLM procedure of SAS.

III – Results and discussion

The pH was similar among treatments (P>0.05) (Table 2). Most of the parameters were affected by the rate of pea inclusion. Gas production was lowest for the 10%Pea concentrate (P<0.05). The average values of gas production recorded was higher than those observed by Bastida Garcia *et al*., (2011) evaluating field pea hay, probably due to the lower degradability of hay compared with concentrates. The potential gas production (*A*) was greater for 0%Pea and 30%Pea than 10%Pea (P<0.01), presenting intermediate values the 20%Pea concentrate. The lack of a lineal effect with the inclusion of Pea could be related with the different inclusion of others ingredients (corn, barley…) because they were modified to obtain an isoenergetic and isoproteic concentrates. The rate of gas production (*c*) was not affected by the inclusion of field pea (P>0.05).

Table 2. Effect of inclusion of increasing proportion of field peas in the fattening concentrate of lambs on the gas and methane production at 24 hours

	Inclusion of field pea				s.e.m.	P-value
	0%	10%	20%	30%		
pH final	6.59	6.56	6.59	6.56	0.0	0.30
Gas production, ml/g OM	192.8a	179.4b	194.7a	201.7a	11.0	0.012
Gas production kinetics						
A, mL	85.5a	80.4c	82.3bc	85.3ab	3.0	0.003
c, h^{-1}	0.113	0.114	0.123	0.119	0.0	0.18
Methane production, ml/g OM	9.2ab	8.1b	8.6b	9.8a	0.9	0.02
Methane: Gas, %	4.7	4.4	4.4	4.8	0.4	0.14
NH3-N, mg/l	132.2a	111.8b	135.5a	129.9a	13.9	0.02
IVOMD, %	91.5ab	92.3a	88.8c	90.3bc	1.5	0.002

A: potential gas production; *c*: rate of gas production. IVOMD: *in vitro* organic matter degradability; s.e.m.: standard error. Means with different letter differ at P<0.05.

The 30%Pea concentrate had greater methane production than the 10%Pea and 20%Pea concentrates (P<0.05). The ratio methane:gas production was not affected by the rate of pea inclusion in the concentrate (P>0.05). The content of NH_3-N was affected by the inclusion of field pea in the concentrate (P<0.05), presenting the 10%Pea concentrate the lowest value.

The organic matter degradability were also affected by the inclusion of field pea (P<0.01, Table 2). The 10%Pea concentrate presented greater IVOMD than the 20%Pea and 30%Pea concentrates, but the 0%Pea concentrate had intermediate value. In contrast, González Garcia *et al*. (2017) did not observe differences in the IVDMD with the inclusion of 0, 25, 50 and 75% of pea replacing soya meal in lamb concentrates. The lack of agreement could be due to the time of incubation which was 96 h in the abovementioned study whereas in the present study the samples were incubated 24 h.

IV – Conclusions

Based on the results from our research it can be concluded that soya can be partially replaced with pea in concentrates of fattening lambs. The use of the concentrate with an inclusion of 10% of field pea would be the most recommended rate, because it reduced gas and methane production and ammonia content whereas it improvement IVOMD.

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Effect of the protein level in maize silage-based diets on performance of early weaned lambs' fattening and carcass characteristics

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Abstract. The aim of this study was to evaluate effects of different protein levels in maize silage-based diets on weaned lambs performance and carcass characteristics. Sixty Moroccan (local breed) early weaned lambs (14.7±0.45 kg initial body weight and 80±6.3 days were divided into three treatments, 20 males each. They received a diet containing maize silage (21%), wheat straw (19%) and concentrate supplement (60% as dry matter basis) with different protein levels, 18 (T1), 16 (T2) and 14 (T3) g crude protein/ 100 g dry matter of the supplement. The trial lasted for 105 days after 14-day of adaptation period. Feed offered and orts were daily registered and feed intake calculated. Lambs were weighed at the beginning and at the end of the trial, and fortnightly in order to determine the average daily gain and feed conversion. At the end of the trial, 3 lambs per each treatment were slaughtered. The carcass dressing percentage, fatness (1-5 scale) and conformation (SEUROP system) were determined. Results revealed that the protein level did not affect either lamb fattening performance or carcass characteristics for the whole period. The ADG was 223.3, 193.9 and 205.4 g/ day for T1, T2 and T3, respectively. Feed conversion ratio was 4.7, 5.6 and 5.5 kg dry matter intake/ kg ADG for T1, T2 and T3, respectively. The dressing percentage and fatness were 56.5, 54.1 and 55.1% and 2.8, 2.3 and 2.5 for T1, T2 and T3, respectively. In conclusion, lambs may be fed maize silage-based diets containing 20 % of maize silage and concentrate feed supplement containing 14% CP during the fattening period without negative effects on lambs performance and carcass characteristics.

Keywords. Protein level – Lamb – Maize silage – Fattening – Carcass.

Effet du niveau protéique des rations à base d'ensilage de mais sur les performances d'engraissement des agneaux sevrés précocement et les caractéristiques de la carcasse

Résumé. *L'objectif ce travail était d'évaluer l'effet du niveau protéique des rations à base d'ensilage de maïs sur les performances d'engraissement des agneaux sevrés précocement et les caractéristiques de leur carcasse. Soixante agneaux sevrés précocement (14,7 ± 0,45 kg de poids vif initial et 85 ± 6,3 jours d'âge) ont été répartis aléatoirement en trois traitements de 20 mâles chacun. Ils ont reçu un régime contenant de l'ensilage de maïs (21%), de la paille de blé (19%) et un supplément de concentré (60% en MS) avec différents niveaux de matières azotées totales (MAT): 18 (T1), 16 (T2) et 14 (T3) g MAT/100 g MS. L'essai a duré 105 jours précédé d'une période d'adaptation de 14 jours. Les quantités distribuées et les refus ont été enregistrés chaque jour pour calculer les quantités ingérées. Les agneaux ont été pesés au début et à la fin de l'essai et tous les quinze jours afin de déterminer le gain moyen quotidien et l'indice de consommation. À la fin de l'essai, 3 agneaux de chaque traitement ont été abattus et le rendement de carcasse, l'état d'engraissement (échelle de 1 à 5) et la conformation (SEUROP) ont été déterminés. Le niveau protéique du régime alimentaire n'a affecté ni les performances d'engraissement ni les caractéristiques de la carcasse. Le gain quotidien moyen (GMQ) a été de 223,3, 193,9 et 205,4, respectivement, pour T1, T2 et T3. L'indice de consommation a été de 4,7, 5,6 et 5,5kg MSI / kg GMQ, respectivement, pour T1, T2 et T3. Le rendement de carcasse et l'état d'engraissement ont été de 56,5, 54,1, 55,1% et 2,8, 2,3 et 2,5, respectivement, pour T1, T2 et T3. En conclusion, les agneaux peuvent être nourris avec des régimes contenant 20% de l'ensilage de maïs et un concentré contenant 14% de MAT pendant la période d'engraissement, sans affecter négativement les performances et les caractéristiques de la carcasse des agneaux.*

Mots-clés. *Niveau protéique – Agneaux – Ensilage de mais – Engraissement – Carcasse.*

I – Introduction

In Morocco, small ruminant production is considered the main source of income for farmers living in arid and semi-arid areas in which they are raised mainly on the available natural rangelands. However, the irregular rainfall (drought season), rangeland degradation (limited forage availability) and high price of supplementary feeding affect negatively the animal productivity and therefore the farmers' income. This situation leads to switch from a traditional feeding system based on the rangelands (extensive production system) to a semi-intensive production system based on concentrate supplementation to maintain a certain level of production's performance. In this production system, the lamb fattening is the most common practice to mitigate the effects of drought. In such situation, silage can be successfully fed to fattening lambs to improve animal performance and pasture utilization (Marley *et al*., 2007; Stanley, 2003). However, the most important factor affecting the forage quality and its utilization is the protein content which can improve the utilization of low-quality forage (Poppi and McClennan, 1995). The use of a low-cost diet through the incorporation of alternative forage resources such as maize silage and protein supplement feeds may constitute a good feeding practice to improve lambs' fattening performance. The objective of this work was to evaluate the effects of the protein level in maize silage-based diets on the fattening performance of early weaned lambs and carcass characteristics.

II – Material and methods

Sixty Moroccan, local breed, early weaned lambs (entire males) with an average initial live weight of 14.7±0.45 kg and age of 80±6.3 days, were randomly assigned to three treatments, (20 animals per treatment). Lambs received a basal diet of maize silage (21%), wheat straw (19%) and concentrate feed (60% as dry matter basis). The concentrate supplement consisted of three crude protein level, 18 (T1), 16 (T2), and 14 (T3) g crude protein/ 100 g dry matter. All used diets were isoenergetic. The chemical composition of diet's ingredient is presented in Table 1. The experiment was lasted for 105 days after a 14-day adaptation period to the experimental diets. Lambs were fed twice daily, and feed offered and orts daily registered. Free clean water and mineral block were available all the time. In addition, Lambs were weighed before morning feeding, at the beginning and the end of the trial, and fortnightly.

Table 1. Chemical composition (% DM) of different experimental diets' ingredients

	Maize silage	Concentrate feed18% CP	Concentrate feed 16% CP	Concentrate feed 14% CP	Wheat straw
Dry matter (DM)	35.12	88.45	88.75	87.37	89.88
Organic matter (OM)	96.31	90.3	90.79	89.03	93.8
Crude protein (CP)	7.91	18.41	16.46	14.36	3.26
Neutral detergent fiber (NDF)	42.66	26.27	26.44	29.04	76.53
Acid detergent fiber (ADF)	25.64	17.46	18.86	21.00	62.06
Lignin	4.42	2.45	3.12	2.43	12.11

At the end of the experiment, and after a 24h period, 3 lambs per each treatment were weighed (slaughter live weight, SLW) and slaughtered, while carcass weight was recorded immediately (Hot Carcass Weight, HCW) to determine the dressing percentage (HCW*100/SLW), the fatness degree (1 to 5 scale) and carcass conformation according to the SEUROP system (Cañeque and Sañudo, 2005).

The effect of protein supplement level on fattening performance (initial fattening weight is used as covariate) and carcass characteristics was analyzed by means of a one-way analysis of variance

according to the model: $Y_{ij} = \mu + Ti + \varepsilon_{ij}$ where *Ti* represents the treatment effect and ε_{ij} the experimental error. The PROC GLM procedure of the SAS statistical package (version 8.01) was used for the analysis. Comparisons among mean values were tested using the LSD test.

III – Results and discussion

1. Fattening performance of early weaned lambs

Initial and final live weights as well as average daily gain (ADG) and feed conversion ratio (FCR) are presented in Table 2. Animals feeding a high protein level (T1) had greater final weights than those in T2 and T3 groups (P=0.0023).The body weight changed between lambs in T1 and T2 was 4 kg (Table 2). However, the protein level did not affect the ADG for the whole period. The feed conversion ratio of lambs varied between 4.7 for T1 and 5.6 for T2. The improved FCR for T1 may be associated with a better feed efficiency of the supplement containing 18% CP that is not significantly reflected in the ADG. Our results agreed with several studies that didn't find any effects of protein level on ADG and FCR (Ríos-Rincón *et al*., 2014; Beauchemin *et al*., 1995) indicating that dietary effects on growth performance were due mainly to energy concentration rather than protein level or degradability of the protein source when finishing diets contained more than 14% of crude protein. This fact may be explained that when the protein supply exceeds the requirement, energy becomes limiting for growth, and the animals no longer respond to additional intakes of protein (Titgemeyer, 2003).

In our experiment, the percentage of inclusion of maize silage was about 20% which may affect the ADG and FCR. In this regard, Van de Vyver *et al*., (2013) found that the inclusion of 50% silage in diets had the best ADG and FCR to other levels of silage maize incorporations.

Table 2. Fattening performance of early weaned lambs fed concentrate feed with different level of crude protein

	Treatment			SEM	P-Value
	T1	T2	T3		
Live weight (LW, kg)					
Initial	14.34	14.50	15.37	–	–
105 days	38.4[a]	34.4[b]	35.7[b]	0.93	0.0023
Average daily gain (ADG, g/d)					
0-30 days	210.5[a]	156.4[b]	142.6[b]	9.39	<.0001
30-60 days	258.6	223.4	268.0	14.42	0.0906
60-105 days	234.5[a]	208.5[ab]	176.1[b]	12.34	0.0069
0-105 days	223.3	193.9	205.4	8.67	0.0607
Feed conversion (kg DMI/ kg ADG)	4.7	5.6	5.5	–	–

T1: Concentrate feed containing 18% CP; T2: Concentratefeed containing 16% CP; T3: Concentratefeed containing 14% CP ; SEM: standard error of the mean; P: probability of the differences;
[a. b] Means with different superscripts are significantly different (P<0.05).

2. Carcass characteristics

Carcass characteristics are given in Table 3. The analysis of variance revealed no significant effect of the crude protein level of the used supplement on dressing percentage and fatness. Similar results were obtained by Beauchemin *et al*., (1995) where the protein level, in high-energy finishing diets, only had small effects on dressing percentage.

Table 3. Carcass characteristics ofearly weaned lambs fed concentrate feed with different level of crude protein

	Treatment			SEM	P-Value
	T1	T2	T3		
WCDP (%)	56.5	54.1	55.1	1.42	0.5302
Fatness	2.8	2.3	2.5	0.12	0.0580
Conformation	R	R	R	–	–

T1: Concentratefeed containing 18% CP; T2: Concentratefeed containing 16% CP; T3: Concentratefeed containing 14% CP; SEM: standard error of the mean; P: probability of the differences; SEM: standard error of the mean; P: probability of the differences; WCDP: Warm Carcass Dressing Percentage.

IV – Conclusions

The results of this experiment showed that lambs may be fed maize silage-based diets containing 20 % of maize silage and concentrate feed supplement containing 14% CP during the fattening period without negative effects on lambs performance and carcass characteristics. However, further trials should be carried out increasing the proportion of maize silage inclusion in the diet and involving aspects related to meat quality (chemical, physical and sensory parameters) in order to complete the concept of the obtained results in the current study.

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Effects of replacing concentrate by irrigated or rain fed corn hay (pre-mature) on the performance of Awassi lambs

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RAbstract. The ability of premature irrigated (IRR) or Rainfed corn as hay to gradually replace concentrate and barley straw was investigated. 21 Awassi lambs of similar weight (32 kg±3.96) were randomly divided into 3 groups (3 males and 4 females). Feeding was adjusted according to live body weight (LBW) at 3%. The control group was always fed a typical fattening diet composed of 60% concentrates (18% CP; 12MJ ME) and 40% barley straw. At the 1st stage (14 days) and 2nd stage (21 days), 30% and 40% of the concentrate was replaced by IRR or rainfed corn hay. During the 3rd stage (21 days) the concentrate and barley straw were totally replaced by *ad libitum* feeding of either IRRI or Rainfed corn hay. The DM yield as hay was 53625 kg DM/ha from IRR and 21710 kg DM/ha from Rainfed corn. LBWG was similar to the Control group during the 1st and 2nd stage. However, when corn hay was fed *ad libitum*, LBWG was higher but not significantly (P>0.05) for the IRR (197 g/day) and the Rainfed (245 g/day) as compared to control (170 g/day). Corn hay can partially or totally replace concentrate. The cost of feeding corn hay was also lower than concentrate and barley straw. The production, storage and feeding of corn hay was easy to apply by small farmers as compared to silage and reduced the cost of feeding and can improve the health status of animals.

Keywords. Awassi Lambs – Fattening – Concentrate – Corn – Hay – Live body weight – Dry matter intake.

Effet du remplacement du concentré par du foin de maïs prématuré irrigué ou pluvial sur la performance des agneaux Awassi

Résumé. *La capacité du foin de maïs prématuré (IRR irrigué ou pluvial) à remplacer le concentré et la paille d'orge a été étudiée. Vingt un agneaux Awassi de poids similaire (32 kg ± 3,96) ont été divisés au hasard en 3 groupes (3 mâles et 4 femelles). Le groupe témoin a été toujours nourri avec un régime d'engraissement typique ((60% concentrés (18% CP; 12MJ ME)) : 40% paille d'orge). Au 1er stade (14 jours), 30% du concentré a été remplacé par du foin de maïs IRR ou pluvial. A la 2ème étape (21 jours), 40% du concentré a été remplacé par du IRRI ou du foin de maïs pluvial. A la 3ème étape (21 jours), le concentré et la paille d'orge ont été totalement remplacés par l'alimentation* ad libitum *de l'IRRI ou du foin de maïs pluvial. Le rendement en matière sèche du maïs IRR était supérieur (53625 kg MS / ha) à celui du maïs pluvial (21710 kg MS / ha). Le GPV était plus élevé pour l'IRR (197 g / jour) et l'aliment pluvial (245 g / jour) par rapport au groupe témoin (170 g / jour). De plus, le coût de l'alimentation du foin de maïs était plus bas que les prix actuels du concentré et de la paille d'orge. La production et l'alimentation du foin de maïs était facile à appliquer par les petits agriculteurs par rapport à l'ensilage et qu'il réduirait le coût de l'alimentation et améliorerait l'état sanitaire des animaux.*

Mots-clés. *Agneaux Awass – Engraissement – Concentré – Maïs – Foin – Gain de poids vif – Ingestion de matière sèche.*

I – Introduction

The production of the ruminant sector in Lebanon is unable to meet the local demands (Slayman *et al.,* 1986). This is mainly due to the shortage in good quality roughages such as hay and silages (Khazaal, *et al.,* 2001, Hamadeh, *et al.,*1996). Sustainable good quality forage production is not well developed due to the Mediterranean climatic conditions (long dry season) where water resources are becoming limited and, irrigated areas are mostly dedicated for industrial and food crop production.

Because of this, cereal crop residues (i.e straws) are considered as the main source of roughages for farmers. However, straw is known to be of low quality and reduce intake and nutrient supply. Thus, in Lebanon and many developing countries the shortage of good quality forages have forced farmers to rely on low quality forages such as straws and higher proportion of concentrates (up to 60-70% of total ration DM) in order to achieve moderate to high level of production.

Excessive concentrate feeding results in acidic rumen pH (<6), less rumination and saliva production. Thus chronic rumen acidosis and several health problems (reduced fiber digestion, milk fat depression, diarrhea, laminitis, liver abscesses, increased production of bacterial endotoxin and inflammation) (Plaizier, *et al.,* 2008).

The objective of the study was to compare the difference in yield and chemical composition of irrigated and non-irrigated premature corn as hay, and to investigate its potential to replacing concentrate as supplement and its effect on the performance (intake, live weight gain LWG and feed conversion) of growing Awassi lambs.

II – Materials and methods

The local variety of corn used is traditionally planted by farmers for human and livestock feeding and also known for its tolerance for drought. This variety is commonly planted in western Lebanon without irrigation in March. The seeds were planted in the Bikaa valley (eastern Lebanon) with 30 cm between rows and 10 cm between plants. Due to the dry conditions in the Bikaa valley the rain fed field resulted in lower yield and the plants were almost like standing hay (Fig. 1).

Fig. 1. Rain fed corn suffering from water scarcity.

Fig. 2. Sun drying corn Stover for 5-7 days in the field.

The corn plants were harvested after 103 days from planting (stage VT) (Fig. 2), sun dried in the field chopped (1-5 cm) and stored until offered to animals. Crude protein (CP) was determined chemically (AOAC.,1990), and fiber by using NIR.

A total of 21 Awassi lambs (32 kg±3.96) (9 females and 12 males) were randomly distributed into 3 groups, each with 3 females and 4 males. The animals were adapted for 2 weeks on a ration consisting of 60% concentrate (18% CP: 12 MJ ME) and 40% barley straw at 3% DMI in two equal meals (morning and afternoon). This was followed by feeding as shown in Table 1.

Table 1. Feeding regimes for every stage (1st, 2nd and 3rd) for all groups (control, irrigated IRR and rain fed)

	Control	Irrigated (IRR)	Rain fed
1st stage (2 wks)	60% Concentrate	42% Concentrate	42% Concentrate
	40% straw	18% Corn hay (irrigated)	18% Corn hay (rainfed)
		40% straw	40% straw
2nd stage (3 wks)	60% Concentrate	36% Concentrate	36% Concentrate
	40% straw	24% corn hay (irrigated)	24% corn hay (rainfed)
		40% straw	40% straw
3rd stage (3 wks)	60% Concentrate	100% corn hay	100% corn hay
	40% straw	(irrigated) (*ad libitum)*	(rainfed) (*ad libitum)*

Total forage DM yield was estimated at 2 stages of growth based on the representative collected samples from 0.5m^2 from each field at the early stage, and before flowering (i.e. at 30 days after plantation and 103 days respectively). Feed refusal was collected every morning before the new meal was offered. DM intake was determined daily for each group. Animals were individually and weekly weighed to determine live weight gain (LWG). Daily DM and nutrients intake (i.e. CP and ME) were calculated according to chemical analysis or from feeding tables. According to AFRC (1993), the ME content of whole maize silage is 11.3 MJ/kg DM. Other references indicated that the ME value of corn silage was 9.4 (MJ/kg DM at few eared stage) (Howard and Shaver, 2018). As the corn hay in this experiment was harvested at premature stage, the value of 9.4 MJ/kg DM of ME was adopted for both irrigated and rain fed corn hay. For statistical data analysis, SPSS STAT was used. The averages of DM and nutrients (CP and ME) and LBW were subjected to one-way ANOVA test.

III – Results and discussion

The yield of dried corn as hay was higher from the irrigated (IRR) plot as compared to rain fed at early stage (5000 kg & 15000 kg for rain fed and IRR plots respectively). The difference became larger at the pre-mature stage (21710 & 53,625 kg for rain fed and IRR respectively). Due to the dry climate and the low rainfall season, there was a massive difference between IRR and rain fed fields. However, the forage yield of IRR corn was slightly lower from that of corn silage reported in the literature (65,700 kg/ha) (Roth *et al*., 2001). As shown in Table 2, both IRR and rain fed corn hay cost was lower than concentrate and straw.

Table 2. Comparison of the cost of irrigated or rainfed corn hay, concentrate and straw

Cost	Irrigated	Rain fed	Concentrate	Straw*
(US $/kg DM)	0.088	0.139	0.322	0.184
(L.L./kg DM)*	133	210	485	277

* 1 US $= 1507 L.L (Lebanese Pound). # add 25000 LL/ton if transported to other regions.

As shown in Fig. 3, and Table 3, daily DM intakes in the first and 2ndstages were approximately equal in the 3 groups as the DM offered was restricted to about 3% of the animals LW.

However, when corn hay was offered *ad libitum* to the IRR and rain fed groups during stage III, their daily DM intake greatly increased (Table 3) to reach 4.8% of the animals' LW when offered ad libitum corn hay at stage 3.

According to Trotter and Keith (1992), when daily DM intake as a % of body weight is higher than 3% the forage is considered as prime or high quality. Therefore, these observed increases in daily DM intake in IRR and rainfed groups was probably due to the positive impact of the corn hay on the rumen environment (pH, rumination and saliva production) maximizing the rumen microbial ac-

tivity and supply of energy and amino acids. Hence, DM intake was far better in the IRR and rain fed groups compared to that of the control group.

As DM intake was controlled during the 1st and 2nd stage, the daily CP and ME consumption was approximately similar in all the 3 groups. However, in the 3rd stage (*ad libitum corn hay)*, daily CP and ME consumption for the IRR and rainfed groups were largely improved as compared to the control group (Fig. 3, Table 3).

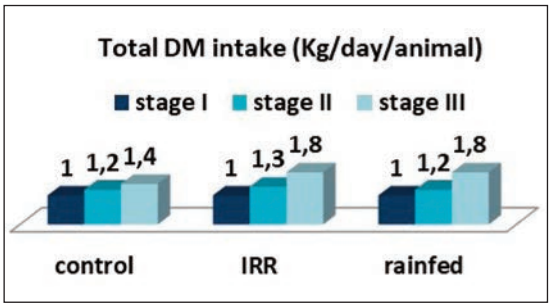

Fig. 3. Total DM intake (Kg/day/animal) of the 3 groups (control, IRR and raid fed).

Table 3. DM intake (%) as a proportion of live bodyweight for the 3 groups of animals at the 3 stages of the experiment

	Stage I	Stage II	Stage III
Control	3.01	3.4	3.45
IRR	2.99@	3.33#	4.9*
Rainfed	3@	3.38#	4.8*

Corn hay: @:30%; #:40%; *:*ad libitum.*

According to the AFRC (1993), the daily nutrients requirement for maintenance of a 40 kg lamb is estimated at 6.5 MJ of ME and 75.4 g of CP. However, in order to gain 200 g of LW per day, the animal and depending on the quality of the diet should be able to consume 1.55 kg of DM and will require 17.9 MJ of ME and a 143.3 g of CP. This level of DMI and estimated nutrients supply was achieved when the animal received corn hay *ad libitum* (Table 3) and as a results achieved 197 g/day and 245 g/day with the rain fed and IRR groups respectively (Fig. 4).

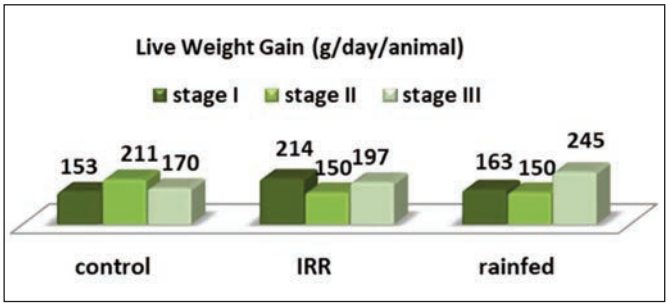

Fig. 4. Average LWG (g/day/animal) in the control, IRR and rain fed groups during the experiment.

IV – Conclusions

The DM yield per hectar, was much higher in IRR than rainfed fields. Thus farmers cannot always rely on rain to irrigate corn especially in drier areas of Lebanon (Bikaa). However, chemically there were no major differences between IRR and rainfed corn hay.

Due to the lower DM yield in rainfed corn hay the cost was higher than IRR corn hay. However, IRR & Rain fed corn hay still cost much less (one third or half) compared to Concentrate, silage or Cereal straw.

The process of producing and feeding corn hay was simple and would be easy to apply by small farmers as compared to the traditional expensive and mechanized silage production process. It can be produced on rainfed or irrigated land.

Premature corn hay can partially or totally replace concentrate and produced better animal performance (DMI &LWG).

Reducing concentrates in the diet will increase profitability, improve animal performance, and reduce animal health risks associated with large quantities of concentrates, such as acidosis, fat liver, fertility, hoof problem and mastitis.

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In vitro digestibility of a pastoral ecotypes collection of *Melilotus officinalis*

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Abstract. The aim of this study was to determinate the *in vitro* enzymatic digestibility of twenty ecotypes of yellow sweet clover (*Melilotus officinalis*) which were collected from the North-West Moroccan pasture. This collection was cultivated in the INRA experimental station in Tangier. The samples were collected during three growth stages of vegetative development. From the vegetative to the flowering stage, the fermentation parameters have also experienced a clear decrease. Indeed, we recorded a very high significant drop (P<0.001) for production of microbial biomass "PMB" (330.84 to 119.17 mg), for partition factor "PF" (4.07 to 2.77 mg/ml), for the speed coefficient of gaz production "c" (0.11 to 0.09 h^{-1}) and for protein digestibility "dE" (49.54% to 26.41% of crude protein "CP"). The gaz production decreased from 216.33 to 179 ml/g in the budding stage and then increased highly to 185.33ml/mg in the flowering stage. The best ecotypes have recoded values of 340.04 mg for PMB, 4.15 mg/ml for PF, 0.11 h^{-1} for c, 64.86% CP for dE. This study showed that yellow Melilot presents a wide genetic diversity of nutritional parameters that can be exhibited in the field of animal nutrition, essentially in the vegetative stage, which presented interesting nutritional parameters.

Keywords. *Melilotus officinalis* – Ecotype – Harvest stage – Digestibility – Enzymatic.

Digestibilité* in vitro *d'une collection d'écotypes pastoraux de Melilotus officinalis

Résumé. *Vingt écotypes de Mélilot* (Mélilotus officinalis) *des pâturages du Nord-Ouest du Maroc ont été installés dans la station expérimentale de l'INRA pour la détermination de leur digestibilité in-vitro par production de gaz et enzymatique. Des fauches ont été réalisées au stade végétatif, bourgeonnement et à la floraison. En allant du stade végétatif à la floraison, les paramètres de fermentation diminuent aussi très significativement, de 330,84 mg à 119,17 mg pour la production de la biomasse microbienne PBM, de 4,07 mg/ml à 2,77 mg/ml pour le facteur de partition (FP), de 0,11 à 0,09 h^{-1} de la vitesse de production de gaz, de 49,54% à 26,41% pour la digestibilité des protéines (dE). La production de gaz a diminué de 216,33 à 179 ml/g au bourgeonnement puis connait une faible hausse à 185,33ml/g à la floraison. Selon les écotypes, les paramètres variaient entre 340,04 et 115,25 mg pour PBM, 4,15 et 2,77 mg/ml pour FP, 0,11 et 0,09 h^{-1} pour c, 64,86 et 22,78% MAT pour dE. Cette étude a montré que le mélilot présente une variabilité significative, cependant, les écotypes E34 et E23 se présentent comme un fourrage prometteur dans l'alimentation caprine.*

Mots-clés. Melilotus officinalis – *Ecotype – Stade de coupe – Digestibilité – Digestibilité enzymatique.*

I – Introduction

In Morocco, goat's production is confronted to pressures of technical, economic and environmental order, which can be limited by improving the food value of the basic feed ration (a good digestibility and a wealth of nutrients) and also by a valorization of the feeding resources locally available not exploited. *Mélilotus officinalis* is a species which pushes naturally in the North-West of Morocco. This leguminous plant can reveal an important agro-economic and nutritional interest considering its availability in the area and his highly content of proteins, phosphorus and calcium (Urness and Al, 1975). The aim of the study was to better know the effect of ecotypes and the stage of plant growth on *in vitro* digestibility and the estimated fermentation parameters.

II – Materials and methods

The seeds of 20 ecotypes (E1, E2, ..., E23) of *Melilotus officinalis* (the yellow sweet clover) collected last year (2017) from various ecological areas of the North-West of Morocco were sown in the Experimental Field of Boukhalef in November 13, 2017. See Lahkim Bennani *et al*. (in this volume) for more information about the collection sites, climate and soil. Each ecotype was installed on a plot of 10x2 m with 1m separation from each other. The plot was subdivided in 5 lines with a line space of 40 cm. Each line is sowing with an amount of 10 g which makes a density of 25 kg/ha. Fermentation kinetics and *in vitro* digestibility were estimated by the *in vitro* method of Menke and Steingass (1989). The rumen fluid used for incubation was taken from three slaughtered goats grazing on forest pasture. The inoculum was prepared as described by Goering and Van Soest (1975). The volume of gas was recorded at 0, 2, 4, 8, 12, 24, 48, 62 and 72 hours of incubation using 100 ml gradual glass syringe plunger. At the end of the incubation, contents of each syringe were used to estimate the potential in vitro dry matter (DM) and organic matter (OM) disappearance (IVDMD and IVOMD, respectively) The potential of gas's production of the soluble and insoluble fraction and also the speed of production of gas were calculated by using the exponential model of Ørskov and Mc Donald (1979). The production of microbial biomass (PBM) and the factor of partition (FP) were estimated by using the formulas of Blümmel (1997). The digestibility of proteins was determined by the protease method (Aufrère and Cartailler., 1988). The effect of the ecotype on the studied parameters was analyzed by the statistical software of analysis SAS (version 9, 2004) by using GLM's procedure. The multiple comparison of average was carried out using test LSD.

III – Results and discussion

The quantity of microbial biomass produced in mg informed on the forage ability to provide essential nutrients (protein and energy) for the proliferation of rumen microorganisms. Indeed, E21, E22, E23 were characterized by an important produced microbial biomass (>306.36 mg). The organic matter degraded (mg) relative to the quantity of gas produced during incubation (FP) was affected significantly by the variability of the ecotypes ($P<0.001$). The higher values were recorded for E21, E22 and E23 with 4.15, 4.08 and 4.07 mg/ml respectively (Table 1). The production of gas coming from the fraction potentially degradable (a) depended very significantly on the origin of ecotypes($P<0.001$). E1 and E2a recorded the higher values with 3.39 and 3.69 ml/g DM respectively.The quantity of gas released by the insoluble fraction potentially degradable (b) depended very significantly on the source of the ecotypes ($P<0.001$). E34 and E13 recorded the higher values with 221.66 and 212.90 ml/g DM respectively. The origin of the ecotypes affected the speed of gas's production of the insoluble fraction (c) with $P<0.001$. The higher values were recorded for E3 and E17 with 0.11 h^{-1}.The variability of ecotypes affected the protein's digestibility ($P<0.001$). The highest value was recorded for E23 with 64.86% DM whereas E1 recorded the minimal value with 22.78% DM (Table 1).

The PBM decreased very significantly while passing from the vegetative stage (330.84 mg) to the flowering's one (119.17 mg) ($P<0.001$). The quantity of average microbial biomass was about 222.52 mg. The factor of partition decreased from the vegetative stage (4.24 mg/ml) to the flowering stage (2.77 mg/ml; $P<0.001$). The factor of partition's average was about 3,44 mg/ml. The production of gas coming from the fraction potentially degradable depended on the development stage ($P<0.01$). The highest value was recorded at the vegetative stage with 2.54 ml/g DM with an average of 0.62 ml/g DM. The quantity of gas by the insoluble fraction depended on plant's development. The maximum value recorded was about 208.87 ml/g DM at the vegetative stage and the average was at 189.18 ml/g DM. The speed of production of gas fell from the vegetative stage with 0.11 h^{-1} to the flowering stage with 0.09 h^{-1}. The average speed was about 0.10 h^{-1} (Table 2). The digestibility of proteins decreased with the advance of the stages. The highest value was recorded during the vegetative stage with 49.54% CP with an average value of 37.86% DM (Table 2).

Table 1. Fermentation parameters of *Melilotus officinalis* ecotypes

Ecotype	PBM (mg)	FP (mg/ml)	a (ml/g DM)	b (ml/g DM)	c '(h^{-1})	dE
E1	219.20±60.13	3.56±0.46	3.39±1.24	191.47±12.67	0.10±0.00	22.78±4.13
E2a	160.16±30.65	3.09±0.22	3.69±1.68	203.53±11.18	0.09±0.00	28.78±4.09
E2	153.60±18.19	2.98±0.11	0.59±0.10	183.43±5.67	0.10±0.00	29.78±2.18
E3	115.26±21.88	2.77±0.12	1.75±0.43	188.33±8.53	0.11±0.00	32.65±2.43
E34	166.68±8.06	3.07±0.11	1.56±0.46	221.66±1.26	0.10±0.01	27.23±2.34
E9	249.74±21.56	3.61±0.17	1.63±0.75	183.33^{f}±8.89	0.09±0.00	36.60±1.72
E10	285.10±42.05	3.81±0.31	0.15±0.01	171.73±3.88	0.10±0.00	38.90±2.05
E11	251.99±39.43	3.65±0.26	3.13±1.59	187.43±9.16	0.10±0.01	30.48±3.06
E12HN	164.14±47.23	3.05±0.27	3.20±1.10	198.73±6.11	0.10±0.00	38.72±5.07
E13	123.52±40.45	2.81±0.21	2.35±1.01	212.90±7.52	0.10±0.00	43.67±3.73
E14	262.73±55.99	3.69±0.33	1.06±0.36	186.60±7.00	0.09±0.00	40.30±4.11
E15	170.40±46.05	3.06±0.26	1.79±0.41	201.13±10.19	0.10±0.00	41.03±3.28
E16	243.17±32.33	3.49±0.24	1.64±0.72	203.37±6.52	0.10±0.00	43.41±4.89
E17	169.89±42.14	3.13±0.26	1.74±0.40	190.67±9.70	0.11±0.00	32.14±2.89
E18	290.10±37.59	3.98±0.32	1.10±0.52	182.90±14.84	0.09±0.00	46.10±4.73
E19	273.16±35.64	3.41±0.35	2.37±0.92	187.40±2.21	0.10±0.00	43.46±2.61
E20	197.16±23.24	3.32±0.16	0.94±0.41	193.63±12.57	0.10±0.01	33.83±5.86
E21	340.04±12.86	4.15±0.05	0.10±0.03	162.93±9.60	0.10±0.00	34.78±4.32
E22	308.11±5.57	4.08±0.15	0.44±0.18	167.97±9.54	0.10±0.00	47.83±3.61
E23	306.36±22.32	4.07±0.22	1.29±0.61	164.37±10.48	0.09±0.01	64.86±2.11
P	<0.001	<0.001	0.0092	<0.001	0.0034	<0.001
Significance	***	***	**	***	**	***

Table 2. Estimated fermentation parameters with the stage of plant growth

Stade	PBM (mg)	FP (mg/ml)	a (ml/g DM)	b (ml/g DM)	c '(h^{-1})	dE
Vegetative	330.84^{a}±10.15	4.24^{a}±0.08	2.54^{a}±0.33	208.87^{a}±3.38	0.11±0.00	49.54a±1.33
Budding	217.57^{b}±11.14	3.30^{b}±0.59	1.21^{b}±0.35	177.60^{b}±2.74	0.10±0.00	37.65b±1.14
Flowering	119.17^{c}±10.95	2.77^{c}±0.06	1.33^{b}±0.19	181.06^{b}±3.73	0.09±0.00	26.41c±1.39
Average	222.52±8.94	3.44±0.06	0.62±0.18	189.18±2.17	0.10±0.00	37.86±1.02
Pro.	<0.0001	<0.0001	0.0035	<0.0001	0.3377	<0.0001
Sign.	***	***	**	***	n.s	***

Concerning digestibility, Gasmi *et al.*, 2012 reported that OMD was 78.1% DM for *Vicia sativa,* 74.6% DM for *H. coronarium*, the values were similar to those found by *Mélilotus officinalis* with an average of 74.84% DM. However digestibility during the vegetative stage was higher for *Melilotus officinalis* with 82.25% than sulla with 77.61% (Errasi, 2016) and to the sainfoin 71.2% (Aufrère *et al.*, 2008). The relation between PBM and OMD is strong (r=0.89), the PBM depended on the source of the ecotypes and the stage of development; the highest values were recorded for E21, E22 and E23 with 340.04, 308.11 and 306.36 mg respectively. The vegetative stage recorded the highest PBM value with 330.84 mg, which is much higher than those found by Errassi *et al.,* 2016 for Sulla with a production of 238.09 mg. The reduction in the microbial production could be the complexation of the tannins with the nutrients that decreases the degree of their availability by the attack of the micro-organisms (Makkar, 2003). The speed of gas's production (c) varied significantly according to the stages; E3 and E17 recorded the highest values with 0.11 h^{-1}. The speed of gas's production decreased from 0.11 h^{-1}, recorded in the vegetative stage to 0.09 h^{-1} recorded in the flowering stage. Values are practically similar to those found by Errassi *et al.,* 2016.

The crude protein digestibility is higher at the vegetative stage, which can explain the high value recorded at this stage with 49.54% DM, whereas E23 recorded the important value with 64.86% DM.

IV – Conclusions

The difference in fermentation's parameters revealed an heterogeneity within the ecotypes which can be related to the chemical composition of the plant. The performances of fermentation and digestibility can be improved by using ecotypes collected at an early stage (vegetative). For this stage, E23 followed by E10 and E14 recorded the highest OMD.

The genotypes of Melilot collected from the pastures of the North-West of Morocco appear as a promising forage resources of goat production, particularly the E23 ecotype which is characterized by a ODM relatively higher for the three stages of harvest, and an interesting profile of fermentation.

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The effect of the inclusion of detoxified *Argania spinosa* press cake into the diet of Alpine goats on the polyphenol compounds and antioxidant properties of the cheese

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Abstract. Goat milk and dairy products, including cheese, are an excellent source of antioxidants known to resist oxidative stress. This research aimed to introduce detoxified Argane press cake (DAPC) in the diet of Alpine goats and to evaluate the effect on antioxidant activity and polyphenol compounds in the cheese. The results showed that the cheese fermented with autochthonous starter obtained from goats fed detoxified Argane press cake showed the highest total phenolic content and DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging assays (160.8 ±5.0 µg GAE/g of cheese dry matter [DM] and 44.76 ±4.1%, respectively) compared to the control cheese obtained from goats fed Argane press cake non-detoxified (100.75 ± 5.1 µg GAE/g DM and 38 ±4.0%, respectively).The collected data revealed that including detoxified Argane press cake in the goat diet offers a good method for raising the amounts of polyphenol compounds and antioxidant activity in goat cheese. Therefore, goat products could be considered as a functional food with benefits for human health.

Keywords. Argane – Goat's cheese – Antioxidant – Polyphenol.

Effet de l'inclusion du tourteaud'* Argania spinosa *détoxifié dans le régime alimentaire des chèvres alpines sur les composés phénoliques et les propriétés antioxydantes du fromage

Résumé. *Le lait de chèvre et ses produits laitiers, y compris le fromage, constituent une excellente source d'antioxydants reconnus pour leur résistance au stress oxydatif. L'objectif de cette étude est d'introduire dans le régime alimentaire quotidien des chèvres alpines le tourteau d'Argane détoxifié (DAPC) et d'évaluer son effet sur l'activité antioxydante et les composés phénoliques du fromage. Les résultats ont montré que le fromage fermenté avec une levure autochtone obtenue à partir du lait de chèvres nourries avec le regime encluant du tourteau d'Argane détoxifié est caractérisée par la teneur la plus élevée en polyphénols ainsi qu'il exhibe un pouvoir antioxydant intéressant (160.8 ± 5,0 µg GAE / g MS et 44.76 ± 4,1%, respectivement) par rapport au fromage témoin fermenté avec une levure autochtone issu du lait des chèvres nourries avec le regime temoin incluant du tourteau d'Argane non détoxifié (100.75 ± 5,1 µg GAE / g de MS et 38 ± 4,0%, respectivement). Les données collectées ont révélé que l'inclusion du tourteau d'Argane détoxifié dans le régime alimentaire des chèvres améliore la qualité du fromage. Par conséquent, les produits à base de lait de chèvre pourraient être considérés comme un aliment nutritionnel présentant des avantages pour la santé humaine.*

Most-clés. *Argane – Fromage de chévre – Antioxidant – Polyphenol.*

I – Introduction

Goat's milk and derivatives are considered healthy food, owing to its composition and recognized benefits for humans (Lakram *et al*., 2019a). Furthermore, goat's milk and cheese exhibit a high antioxidant capacity which reflects greater oxidative stability and improve health protection for the consumer against exposure to the oxidative stress, which is known as characteristic of several acute and chronic diseases (Lakram *et al*., 2019a). The antioxidant activity of goat's milk and cheese can be due to a large variety of functional components, such as phenols, flavonoids, carotenoids, and vitamins (E and C), or even proteins. Additionally, results of two studies using the same antioxidant test show that dairy products have an antioxidant capacity of the same order of magnitude as cereals, legumes and fruit juice (Wu *et al*., 2004,Cloetens *et al*., 2013).

Goat farming in Morocco is considered an important socioeconomic sector. The Moroccan goat population estimated at around 5.3 million heads (Lakram *et al*., 2019b). However, ruminants in Morocco's arid and semiarid areas suffer from lack of forage and water availability due to low precipitation (Mercha *et al*., 2019). For these reasons, it is necessary to contribute to the development of native forage resources adapted to local climate and soil conditions as an alternative resource. Among such native resources, Argane press cake (APC), a by-product of oil extraction from Argane seeds. Unlike other forages, APC has high levels of crude protein (48.4%), crude fiber (17.6%), and fat (18.9%). It is therefore a major source of protein and energy to fill the gap in food rations in the Moroccan livestock (Lakram *et al*., 2019c). On the other hand, it contains antinutritional factors such as saponins (4%), which give it a bitter taste. The astringent and irritating flavor of saponins reduces feed intake. In order to improve its quality and make it more appetizing by livestock, detoxification of the APC is carried out at the National Institute of Agronomic Research (INRA) in Rabat (Morocco). The objective of the present study was to investigate the effect of the inclusion of detoxified Argane press cake into the diets of the Alpine goat on antioxidant activity and polyphenol compounds in the cheese.

II – Materials and methods

The study was conducted on a farm in the region of Meskala (Essaouira, in the region of Marrakech Safi). A follow-up was conducted over a period of six weeks on two groups of eighteen goats. The first group of goats consumed a diet including detoxified Argane press cake (DAPC), while the second group consumed a diet with non-detoxified Argane press cake (APC), a fifteen day adaptation period was respected. The ingredients and chemical composition are shown in Table 1.

Table 1. Ingredients and chemical composition of the diets

	Diet 1	Diet 2
Ingredients (g/100g of fresh matter)		
Argane press cake detoxified	20%	0
Argane press cake no detoxified	0%	20%
Corn silage	16%	16%
Lucerne	17%	17%
Wheat bran	15%	15%
Ground carob	16%	16%
Barley	14%	14%
Concentrate	0	0
Minerals and vitamins	2%	2%
Chemical composition		
Dry matter (%)	89.59	88.12
Crude protein (%)	17.95	18.05
Ash (%)	7.58	8.23
Crude fiber (%)	18.15	15.27
Ether extract (%)	1.78	4.53

The experiment used the response surface methodology to optimize the various detoxification factors (volumes of water, boiling temperature and time) for better saponin reduction from APC. The optimum conditions for detoxifying APC are to boil APC in distilled water at 80 °C for 25 minutes and then to dry it at 40 °C in a hot air oven.

For making cheese, autochthonous starter cultures consisting of a mixture of *Lactococcus lactis* and *Streptococcus thermophilus* were used.

The two groups of bio-cheese were made from goats feed DAPC or APC as described by Jamaly *et al*., (2011).

The total phenolic content (TPC) was determined according to Lakram *et al*., (2019a).The antioxidant activity was determined by measuring the free radical scavenging cheese extract using DPPH inhibition assay as described by Lakram *et al*., (2019a).

Results are expressed as means ± standard deviation (SD). Significant differences between means were tested by ANOVA followed by Tukey's studentized range test at $P<0.05$.

III – Results and discussion

DPPH inhibition of cheese from milk from goats fed DAPC was higher than that from milk obtained from goats fed APC diet over the storage period (14 days in 4°C) as shown in Fig. 1. On day 14, highest DPPH inhibition was shown by DPAC cheese, 44.76±4.1%, while cheese made with milk from goats fed APC showed 38±4.0% .

The percentage of DPPH radical scavenging activity is affected by several factors such as goat feeding, pasteurization and the type of bacterial culture involved in the maturation (Meira *et al*., 2012).

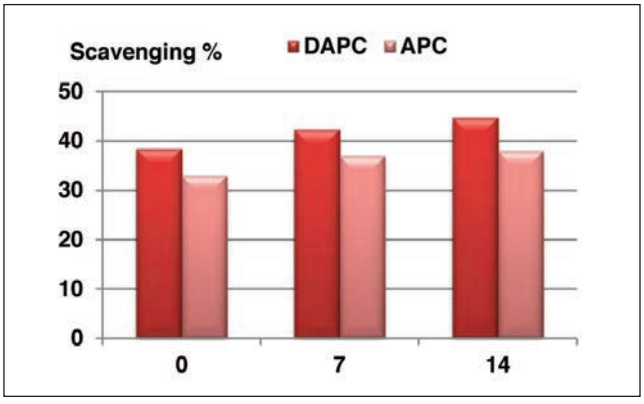

Fig. 1. Changes in antioxidant activity (scavenging % of DPPH) ofgoat's cheese during refrigerated (4°C) storage in days (14 days). APCD: cheese made with milk from goat fed Argane press cake detoxified; APC: cheese made with milk from goat fed Argane press cake non-detoxified. Values are presented as mean ± SD (n = 3).

The total phenolic contents (TPC) estimated by the Folin–Ciocalteu reagent method of the different cheeses analyzed are presented in Fig. 2, the phenolic content followed the same tendency; the highest levels in cheeses made with milk came from goats fed DAPC, averaging 160.8 ±5.0 µg GAE/g of cheese DM, compared to that made with milk obtained from goats fed APC (100.75 ± 5.1µg GAE/g of cheese DM). These values are close to those found by Delgadillo Puga *et al*., (2009).

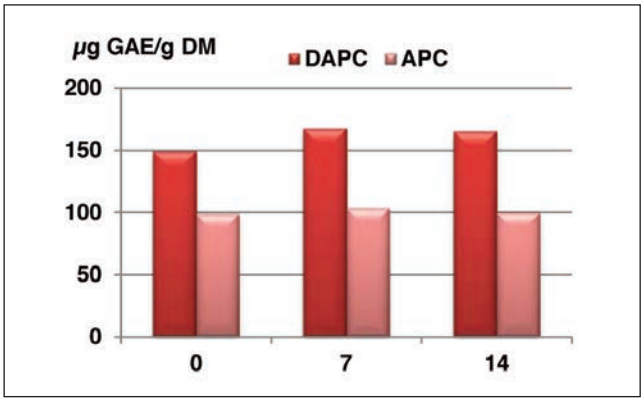

Fig. 2. Changes in total phenolic content (TPC; µg GAE/g of cheese DM) of goat's cheese during refrigerated (4°C) storage in days (14 days). APCD: cheese made with milk from goat fed Argane press cake detoxified; APC: cheese made with milk from goat fed Argane press cake non-detoxified. Values are presented as mean ± SD (n = 3).

Liu *et al*., (2018), when comparing two feeding systems, showed that TPC concentrations were affected by the animals' feed; this finding is in accordance with our results

IV – Conclusion

Although during the last decade's goat cheese has been the subject of many studies throughout the world, very few investigations have focused on the quality of cheese produced in Morocco. The use of a diet based on the argane tree sub products in replacement of a traditional one in goat's diets affect the cheese antioxidant activity and polyphenolic compounds significantly. The diet appears to be a promising alternative for dry season feeding systems and, thereby, to improve the livelihood of farmers in dry area.

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Effect of use of olive mill wastewater for moistening of dry beet pulp in diets on fattening performance of lambs, carcass characteristics and meat quality

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Abstract. The objective of this study was to evaluate the effect of use of olive mill wastewater (OMW) for moistening dry beet pulp in lambs' diet on fattening performance, carcass characteristics and meat quality. OMW were used to replace partially or totally water used for moistening the dry beet pulp (DBP). Twenty four crossbreed lambs "D'man x Boujaad" were randomly assigned to 4 treatments: T1 containing 27% alfalfa, 11% barley straw and 62% barley grain; T2 containing 26% alfalfa, 10% straw, 32% barley grain and 32% PSB (humidified with100% water); T3 containing 26% alfalfa, 10% straw, 32% barley and 32% PSB (humidified with 50% water and 50% OMW), T4 containing 26% alfalfa, 10% straw, 32% barley grain and 32% PSB (humidified with 100% OMW). The fattening trial was lasted 70 days after 7-days of adaptation period and lambs were weighed at the beginning and at the end of the trial, and fortnightly. At the end of the trial, lambs were slaughtered and the carcass dressing percentage (CDP), fatness (1-5 scale), conformation (SEUROP system), ruminal pH, pH of meat at 0 and 24h postmortem, fat deposition (mesenteric and pelvic fat) were determined. The use of OMW for moistening of dry beet pulp in the lamb diet did not affect the average daily gain, ruminal pH, cold CDP, fatness, conformation, pH of meat at 0 and 24h postmortem and fat deposition (mesenteric and pelvic fat). The average daily gain of lambs was 214.5, 236.8, 219.2 and 217.6 g/d for T1, T2, T3 and T4, respectively. The cold CDP was 47.7, 47.3, 47.3 and 47.7 for T1, T2, T3 and T4, respectively.

Keywords. Olive mill wastewater – Lamb – Fattening – Carcass – Meat.

Effet de l'utilisation des margines pour l'humidification de la pulpe sèche de betterave dans le régime alimentaire des agneaux sur les performances d'engraissement, les caractéristiques de la carcasse et la qualité de la viande

Résumé. *L'objectif de cette étude était d'évaluer l'effet de l'utilisation des margines pour l'humidification de la pulpe sèche de betterave dans le régime alimentaire des agneaux sur les performances d'engraissement, les caractéristiques de la carcasse et la qualité de la viande. Les margines ont été utilisées pour remplacer partiellement ou totalement l'eau utilisée pour humidifier la pulpe de betterave sèche (PSB). Vingt-quatre agneaux croisés D'man*Boujaad ont été répartis au hasard en 4 traitements: T1 contenant 27% de luzerne, 11% de paille d'orge et 62% d'orge grain; T2 contenant 26% de luzerne, 10% de paille, 32% d'orge grain et 32% de PSB (humidifié avec 100% d'eau); T3 contenant 26% de luzerne, 10% de paille, 32% d'orge grain et 32% de PSB (humidifié à 50% eau et 50% margines), T4 contenant 26% de luzerne, 10% de paille, 32% d'orge grain et 32% de PSB (humidifié à 100 % margines). L'essai a duré 70 jours après une période d'adaptation de 7jours. Les agneaux ont été pesés au début et à la fin de l'essai et tous les quinze jours. À la fin de l'essai, les agneaux ont été abattus et le rendement en carcasse (RC), l'état d'engraissement (échelle de 1 à 5), la conformation (système SEUROP), le pH du rumen, le pH de la viande à 0 et 24h post mortem, le dépôt adipeux (gras mésentériques et pelvien) ont été enregistrés. L'utilisation des margines pour l'humidification de la pulpe sèche de betterave n'a pas eu d'effet significatif sur le gain moyen quotidien (GMQ), le pH ruminal, le RC froide, l'état d'engraissement, la conformation, le pH de la viande à 0 et 24h post-mortem et le dépôt de gras (gras mésentérique et pelvien). Les GMQ enregistrés étaient de 214,5, 236,8, 219,2 et 217,6 g/j respectivement pour T1, T2, T3 et T4. Le RC froide était respectivement de 47,7, 47,3, 47,3 et 47,7% pour T1, T2, T3 et T4.*

Mots-clés. *Margines d'olive – Agneaux – Engraissement – Carcasse – Viande.*

I – Introduction

Morocco is considered as one of the world's largest olive producer with a production, of 2 millions tons in 2018 of which about 65% is used for the extraction of olive oils. This operation generates large amounts of olive mill wastewater which consists mainly of water used in washing and olives soluble substances. The treatment of one ton of olive produces between 0.5 and 3.25 m^3 of olive mill wastewater (Paraskeva and Diamadopoulos, 2006). These by-products are very rich in monosaccharide (Fezzani and Ben Cheikh, 2009) and mineral substances (Ranalli, 1991) mainly potassium (47%), carbonates (21%), phosphates (14%) and sodium (7%) (Fiestas and Padilla, 1992). The direct discharge of OMW into natural environment constitutes a serious problem of the olive industry due to its highly polluting potential, including soil contamination, water pollution and emission of greenhouse gases after fermentation (Rinaldi *et al*., 2003). One of the most widely-used management options of these by-products, in Morocco, is natural evaporation in storage ponds. This method produces a solid phase which can be used mainly as amender of fertilizer. Other alternative of OMW revalorization is to use it in ruminant feeding. In this context, the objective of this work was to assess the effect of use of olive mill wastewater (OMW) for moistening dry beet pulp diet on in lambs' fattening performance, carcass characteristics and meat quality.

II – Material and methods

Twenty four synthetic breed lambs "Dman x Boujaad" with initial weight of 36 ± 4 kg and age 12 ± 1 month were randomly divided into four treatments of 6 animals: T1 (27% alfalfa hay, 11% barley straw and 62% barley grain); T2 (26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% water)); T3 (26% alfalfa, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 50% water and 50% OMW)); T4 (26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% OMW). The trial lasted 70 days preceded by 7 days of adaptation. All used diets are iso-energetic and iso-nitrogenous. Free clean water and mineral block were available all the time. Lambs were weighed before morning feeding, at the beginning and at the end of the trial and each week during the first month and every two weeks for the rest of trial. The controlled parameters concerned the feed intake and the average daily gain (ADG). At the end of the trial, all lambs were sacrificed and carcass dressing percentage, fatness (1-5 scale), conformation (SEUROP system), ruminal pH, pH of meat at 0 and 24h postmortem and fat deposition (mesenteric and pelvic fat) were determined.

The data analysis was done using ANOVA according to the following statistical model: $Yij = \mu + ai + eij$, where Yij = performance of the animal (i) receiving diet (j); μ = general average; ai = effect of diet; eij = the residual error. The PROC GLM procedure of the SAS statistical package was used for the analysis. Comparisons among mean values were tested using the LSD test.

III – Results and discussion

1. Fattening performances

Final live weight and average daily gain (ADG) as well as feed conversion ratio (FCR) and feeding cost are presented in Table 1. The ADG values recorded in lambs fed T2 were not significantly higher (P=0.5841) than those recorded in the treatments. The replacement of water by OMW for moistening dry beet pulp reduces feed conversion and feeding cost.

The use of OMW for moistening of dry beet pulp did not affect the studied parameters (Table 1). Similar results were obtained by Christodoulou *et al*. (2008) who reported that the incorporation of fermented OMW in fattening lambs diet (alfalfa hay and soybean) did not affect growth parameters or carcass characteristics compared to a control diet based on barley grain, dry beet pulp and alfalfa hay.

Table 1. Final body weight, average daily gain, feed conversion and feeding cost of different used diets

Parameters	Treatments				SEM	P
	T1	T2	T3	T4		
Final body weight (kg)	50.6	52.8	51.2	52.8	1.99	0.8128
Average daily gain (ADG, g/d)	214.5	236.8	219.3	217.6	12.33	0.5841
Feed conversion (Kg DMI/ Kg ADG)	6.7	7.4	7.1	6.7	–	–
Feeding cost (MAD/kg ADG)	18	20.6	20	18.6	–	–

T1: diet containing 27% alfalfa hay, 11% barley straw and 62% barley grain; T2: diet containing 26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% water); T3: diet containing 26% alfalfa, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 50% water and 50% OMW)); T4: diet containing 26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% OMW). SEM: standard error of the mean; P: probability of the differences; MAD: Moroccan dirham (1 MAD= 0.09 €).

2. Carcass characteristics and meat quality

Table 2 shows the obtained results related to carcass characteristics and meat quality. No significant effect is recorded on the studied parameters (P>0.05). However, we noted a slight, but not significant, superiority of the full rumen weight recorded in lambs of T4 in which dry beet pulp was moistened by 100% of OMW and the ruminal pH is more acid. This lower value of pH can be explained by the high acidity of OMW (about 4.55) (Achak *et al*., 2008) which may affect the ruminal pH. The addition of OMW (rich in anti-nutritional substances) may lead to the disturbance of the ruminal fermentation mainly that of fibers and consequently to a slow transit time of the diet through the reticulum-rumen (Theriez and Boule, 1970).

Our results are consistent with those of Christodoulou *et al*. (2008) who reported that the incorporation of fermented OMW in the fattening lambs' diet affected neither fattening performance nor carcass characteristics.

Table 2. Carcass characteristics and meat quality of lambs fed different diets (n=6)

Parameters	Treatments				SEM	P
	T1	T2	T3	T4		
Full rumen weight (kg)	5.53	5.17	4.86	5.99	0.512	0.5269
Empty rumen weight (kg)	0.91	0.82	0.82	0.86	0.067	0.7087
Ruminal pH	6.93	6.97	6.90	6.86	0.106	0.9018
Mesenteric fat (kg)	1.02	1.13	1.31	1.22	0.107	0.3442
Warm carcass dressing percentage (%)	49.2	48.9	49.2	49.3	0.82	0.9852
Cold carcass dressing percentage (%)	47.7	47.3	47.3	47.7	0.75	0.9611
Meat pH at slaughtering (pH0)	6.50	6.39	6.47	6.46	0.086	0.8368
Meat pH 24 h postmortem (pH24)	5.71	5.69	5.72	5.79	0.035	0.2783
Pelvic fat (kg)	0.62	0.64	0.75	0.59	0.078	0.5791
Conformation	3.50	3.50	3.50	3.80	0.129	0.3526
Fatness	2.67	2.67	2.80	2.70	0.145	0.9176

T1: diet containing 27% alfalfa hay, 11% barley straw and 62% barley grain; T2: diet containing 26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% water); T3: diet containing 26% alfalfa, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 50% water and 50% OMW)); T4: diet containing 26% alfalfa hay, 10% barley straw, 32% barley grain and 32% dry beet pulp (moistened with 100% OMW). SEM: standard error of the mean; P: probability of the differences.

IV – Conclusions

Olive mill wastewater can be used for moistening the dry beet pulp used in the fattening lamb diet without affecting the fattening performance, the characteristics of the carcass and the meat quality. The addition of these compounds to fattening lambs' diets reduces the feed conversion and consequently the feeding cost and preserves the environment.

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Biomass, chemical composition and digestibility of some vegetable and legume residues for ruminants in the Chaouia area

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Abstract. This study was carried out to evaluate the biomass, chemical composition and in vitro dry matter digestibility (IVDMD) of some crop by-products. Two categories were evaluated. First group included vegetable residues such as cauliflower (CR), sweet potato (SPR), fennel (FR), vegetable beet (VBR), artichoke (AR), turnip (TR), carrot (CAR) and the second group included legume residues such as bean (BR), lentil (LR) and pea (PR). The total dry biomass was evaluated by the quadrat method at harvesting. It was approximately 100,000 tons of which 76% are legume residues. The dry matter (DM) varied between 13.5 % in VBR to 19.7 % in SPR while the average was about 95.1% for legume residues. The lowest crude protein (CP) content was recorded in PR showing 57.8 g / kg DM while the highest was from the VBR with 181 g / kg DM. The legume residues (BR, LR and PR) recorded higher neutral detergent fiber (NDF) values of 487, 472.8 and 500 g / kg DM, respectively. The average acid detergent fiber (ADF) content of vegetable and legume residues was 227 and 394 g / kg DM, respectively. Acid detergent lignine (ADL) ranged from 16.6 in CR to 108 g / kg DM in LR. Ash content of vegetable residues ranged from 118 in SPR to 279 g / kg DM in VBR and was on average 114 g / kg DM in legume residues. The TR recorded the highest IVDMD being 66 % followed by VBR 61.6 % with the lowest value obtained for SPR being 32.7 %. The biomass of different crops by-products is not negligible and could be used as part of the diet of ruminants according to their nutritive value

Keywords. By-products – Biomass – Nutritive value – Animal feed – Low rainfall area.

Rendement, composition chimique et digestibilité des résidus de quelques cultures maraichères et de légumineuses alimentaires pour ruminant dans la région Chaouia

***Résumé**. L'objectif de ce travail est d'évaluer le rendement, la composition chimique et la digestibilité in vitro de la matière sèche (DIVMS) de deux catégories de résidus de cultures. Les résidus de cultures maraichères à savoir le chou-fleur (CF), la patate douce (PD), le fenouil (FN), la betterave potagère (BR), l'artichaut (AR), le navet (NV), la carotte (CAR) et les résidus de légumineuses alimentaires tels que la fêve (FV), la lentille (LT) et le petit pois (PP). Le rendement sec a été évalué par la méthode des quadrats au moment de la récolte. Il est estimé à 100 000 tonnes, dont 76 % sont les résidus de légumineuses. La matière sèche (MS) variait entre 13,5 % pour BR et 19,7 % pour PD et était en moyenne de 95,1 % pour les résidus de légumineuses. La faible teneur en protéines brutes (PB) a été enregistrée dans les PP, avec 57,8 g / kg de MS tandis que les BR ont la teneur la plus élevée 181 g / kg MS. Les résidus de légumineuses (FV, LT et PP) ont enregistré les valeurs les plus élevées de fibres au détergent neutre (NDF) de 487, 472,8 et 500 g / kg MS, respectivement. La teneur moyenne en fibres au détergent acide (ADF) des résidus de maraichage et de légumineuses était respectivement de 227 et 394 g / kg de MS. La lignine variait de 16.6 pour CF à 108 g / kg MS pour LT. La teneur en cendres des résidus de maraichage variait de 118 pour PD à 279 g / kg MS pour BR et était en moyenne de 114 g / kg MS pour les résidus de légumineuses. Les NV ont enregistré la DIVMS la plus élevée (66 %), suivi des BR (61,6 %), alors que les PD sont les moins digestibles (32,7 %). La biomasse de différents sous-produits de culture est non négligeable et pourrait être valorisée dans l'alimentation des ruminants en fonction de la variabilité de leurs valeurs nutritive.*

***Mots clés.** Résidus de culture – Biomasse – Valeur nutritive – Alimentation animale – Zone à faible pluviométrie.*

I – Introduction

Feeding ruminant is a challenge for the development of animal production in low rainfall areas. In these areas, forage is limited and poorly diversified, rangelands are deteriorated quantitatively and qualitatively and animal feeds are expensive. The search for alternative feed resources is a solution to reduce the cost of production without affecting productivity. These alternatives include crop residues, agro-industry by products or any resource that may be used in animal feeding. Proper use of these resources in animal feeding requires knowledge of their chemical composition and nutritive value. The objective of this work was to evaluate the availability of some vegetable and legume residues in the Chaouia region and to provide information concerning their nutritive value.

II – Materials and methods

After harvesting, the remaining parts of seven vegetables and three legumes were studied. The former included cauliflower (*Brassica oleracea* var *botrytis*), sweet potato (*Ipomoea batatas*), fennel (*Foeniculum vulgare*), vegetable beet (*Beta vulgaris* subsp. *Vulgaris*), artichoke (*Cynara scolymus*), turnip (*Brassica rapa* subsp. *Rapa*), carrot (*Daucus carota* subsp. *Sativus*). The later were bean (*Vicia faba*), lens (*Lens culinaris*) and pea (*Pisum sativum*). Vegetable residues samples were collected at the North of Chaouia while the legume residues were collected from the center of the same area.

Residues from each crop were collected from 4 plots. On each plot (0.5 ha), nine squares of $1m^2$ were distributed uniformly during the harvesting period. Collected residues from each square were weighed in the field and were placed in a bag. After drying at 50°C untill constant weight, three composite samples per plot were prepared.

Ash was determined by calcining the sample in the oven at 550 °C for 6-7 hours. Crude protein (CP) and crude fiber (CF) were determined respectively by Kjeldahl method (AOAC, 1990) and Weende method (AOAC, 1990). Neutral and acid detergent fibres and acid detergent lignin (NDF, ADF, ADL) were determined according to Van Soest *et al*. (1967) and in vitro dry matter digestibility (IVDMD) was obtained by Tilly and Terry method (1967). Data of chemical composition and IVDMD were subjected to analysis of variance while the least significant differences test was used to compare the samples means. Differences were accepted when $P < 0.05$)

III – Results and discussion

1. Yield

Total dry biomass collected was estimated at 100,000 tonnes of which 76% was legume food residues (Table 1). The highest yield was recorded in fennel and vegetable beet residues showing 40.83 q / ha and 39.58 q / ha, respectively. While the yield of legume food residues at harvest were 12.69; 12.8 and 15.19 q / ha respectively for bean, lens and pea.

2. Chemical composition

Vegetable residues at harvest were rich in water. Their dry matter content varied between 19.7% in sweet potato residue to 13.5% in vegetable beet residue while food legume residues were almost dry at harvesting and their humidity was around 5 % (Table 2).

Table 1. Biomass of differents vegetable and legume residues

	Yield at harvest (q/ha)	Dry biomass (t)
Vegetable residues		
Cauliflower residue	32.7	4,604
Sweet potato residue	29.2	4,542
Fennel residue	40.8	4,750
Vegetable beet residue	39.6	4,092
Artichocke residue	34.2	4,820
Turnip residue	23.3	4,036
Carrot residue	30	8,760
Food legume residues		
Bean residue	12.7	20,560
Lens residue	12.8	22,600
Pea residue	15.2	21,360
Total		100,127

Table 2. Chemical composition and *in vitro* dry matter digestibility (IVDMD) of vegetable and food legume straws

	DM (%)	Ash (%DM)	CP (%DM)	CF (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	IVDMD (%)
Vegetable residues								
Cauliflower residue	14.4^{f}	17.6^{c}	11.4^{b}	20.7^{b}	28.3^{a}	19.1^{a}	1.7^{a}	53.9^{c}
Sweet potato residue	19.7^{b}	11.8^{a}	14.7^{c}	27.4^{c}	39.8^{d}	27.8^{c}	6.7^{c}	32.7^{a}
Fennel residue	15.5^{d}	21.1^{d}	13.7^{c}	21.1^{b}	26.5^{ab}	23.8^{b}	6^{bc}	54.6^{c}
Vegetable beet residue	13.5^{e}	27.9^{e}	18.1^{e}	18.8^{a}	32.4^{c}	18.2^{a}	6.9^{c}	61.6^{e}
Artichocke residue	13.5^{e}	18.8^{c}	13.1^{c}	21.1^{b}	39.9^{d}	25.4^{f}	5.6^{bc}	48.5^{b}
Turnip residue	15.1^{d}	17.2^{c}	10.5^{b}	24.2^{c}	29.5^{b}	20^{a}	5.6^{bc}	66^{f}
Carrot residue	17.3^{c}	14.7^{b}	16.8^{d}	20.8^{b}	26.3^{a}	19.5^{a}	5^{b}	57^{d}
Average	15.6	18.4	14.1	21.6	31.8	22	5.4	53.5
Legume residues								
Bean residue	95.0^{a}	11.1^{a}	6.4^{a}	35.1^{e}	48.7^{e}	41.3^{e}	9.3^{d}	50.3^{b}
Lens residue	95.5^{a}	11.3^{a}	6.8^{a}	32.3^{d}	47.3^{e}	38.6^{d}	10.8^{e}	50.6^{b}
Pea residue	94.9^{a}	11.7^{a}	5.8^{a}	33.2^{d}	49.9^{f}	38.2^{d}	8.2^{d}	58.8^{d}
Average	95.1	11.4	6.4	33.5	48.6	39.4	9.4	53.2

Values in the same columns followed by different letters are significantly different ($P < 0.05$).

The crude protein content of vegetable residues ranged from 10.5 to 18.1 % DM. The highest value ($P < 0.05$) was recorded in vegetable beet residue while the lowest ($P < 0.05$) was recorded in turnip residue. Gasa *et al*. (1989) obtained 14.3 % DM for cauliflower residue while Bakshi *et al*. (2016) and Mahgoub *et al.* (2018) reported a higher nitrogen content for cauliflower leaves 17% DM and 23 % DM respectively. The average protein content of food legume residues was 6.35 % DM, which is almost twofold of cereal straw (Muñoz, 1991). Haddad and Husein (2001) found higher protein content (8.2 % DM) for lens residue.

The average CF content was 21.6 and 33.5 % DM, respectively, in vegetable and food legume residues. The lowest value ($P < 0.05$) was noted in vegetable beet.

Food legume residues recorded the highest value of neutral detergent fiber (48.6 % DM). ADF and ADL values were 22 % DM and 39.4 % DM and 5.4 % DM and 9.4 % DM, respectively in vegetable and legume residues.

Turnip residue had the highest IVDMD (66%) while sweet potato residue was the least digestible (32.7%). Pea residue recorded the highest IVDMD among food legume residues of which remains high compared with IVDMD cereal straw (Muñoz, 1991).

IV – Conclusions

Vegetable and food legume residues studied in this work generate a significant biomass that can be valorized in animal feeding in low rainfall area where forage resources are limited. The chemical composition and digestibility are better than those of cereal straw commonly used as fodder. Further studies still needed to elucidate the incorporating rates in ruminant diets and adequate conservating methods.

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Plant secondary compounds in Mediterranean shrubs: Phytotoxins or medicines

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Abstract. Plant secondary metabolites (also called phytotoxins; natural products) are molecules existing in most vascular plants that are not necessary for their survival, but in higher concentrations they protect plants from consumers or from pathogens. These phytochemicals can adversely affect cellular and metabolic processes in herbivores, but also at low doses and in appropriate mixtures, they can have beneficial effects on animal nutrition, health and other therapeutic impacts. In this paper, we demonstrate the potential effects of plants with medicinal properties on animal foraging behavior as a function of the consequences they experience after ingestion of Mediterranean shrubs that are rich in phytotoxins. This mechanism –behavior by consequences– suggests animals are able to meet nutritional requirements and self-select certain plants with medicinal properties if they are offered the opportunity to do so when foraging in diverse Mediterranean shrub communities. Understanding the feeding behavior of ruminants when offered a variety of plant species is necessary to be able to improve their health and well-being by reducing levels of stress and fear; it may also lead to the early detection of illness. Thus, management strategies in biochemically/biologically diverse ecosystems should benefit from allowing ruminants to manifest their feeding preferences.

Keywords. Mediterranean shrubs – Herbivores – Secondary compounds – Medicinal plants – Phytotoxins.

Composés secondaires végétaux dans les arbustes méditerranéens : phytotoxines ou médicaments

***Résume**. Les métabolites secondaires de plantes (également appelés phytotoxines; produits naturels) sont des molécules fabriquées dans la plupart des plantes vasculaires qui ne sont pas nécessaires à leur survie, mais qui, à des concentrations plus élevées, les protègent des consommateurs ou des agents pathogènes. Ces composés phytochimiques peuvent avoir des effets néfastes sur les processus cellulaires et métaboliques chez les herbivores, mais aussi à faibles doses et dans des mélanges appropriés, ils peuvent avoir des effets bénéfiques sur la nutrition, la santé et d'autres effets thérapeutiques des animaux. Dans cet article, nous démontrons les effets potentiels de plantes ayant des propriétés médicinales sur le comportement alimentaire des animaux en fonction des conséquences qu'elles subissent après l'ingestion d'arbustes méditerranéens riches en phytotoxines. Ce mécanisme –comportement par conséquences– suggère que les animaux sont capables de satisfaire les besoins nutritionnels et de sélectionner eux-mêmes certaines plantes aux propriétés médicinales si l'on leur en donne la possibilité lorsqu'elles cherchent de la nourriture dans diverses communautés arbustives méditerranéennes. Comprendre le comportement alimentaire des ruminants lorsqu'on leur propose une variété d'espèces végétales est nécessaire pour pouvoir améliorer leur santé et leur bien-être en réduisant les niveaux de stress et de peur. Cela peut également conduire à la détection précoce de la maladie. Ainsi, les stratégies de gestion dans des écosystèmes diversifiés biochimiquement/biologiquement devraient permettre aux ruminants de manifester leurs préférences en matière d'alimentation.*

***Mots-clés**. Arbustes méditerranéens – Herbivores – Composés secondaires – Additifs alimentaires – Plantes médicinales – Phytotoxines.*

I – Introduction

Ruminants foraging on Mediterranean rangelands encounter plant species that differ in their flavor and nutrient concentrations. Plants also contain secondary compounds that at excessive doses in plants can adversely affect herbivores through their negative actions on cellular and metabolic processes (Cheeke, 1998), but at the appropriate doses many of these phytotoxins may have medicinal benefits. The influence of plant secondary compounds on diet selection of mammalian herbivores is recognized (Mc Arthur *et al.,* 1991; Mc Arthur *et al.,* 1993; Duncan *et al*., 1994), and it is known that interspecific differences exist among ruminants for tolerance and response to phytochemical defenses. However, interspecific differences in diet selection in response to phytochemical compounds have received little consideration as a basic factor influencing diet selection of herbivores. In plant communities with a diversity of plants species, animals may consume a variety of foods, and thus they can potentially benefit from secondary compounds in their diet. At appropriate doses, secondary compounds can benefit ruminants through suppression of bacteria, parasites, and fungi that inhabit herbivores bodies and cause impairment of herbivore health (Engel, 2002). The nature of this dual action (i.e., toxin/medicine) is merely a matter of dosage and a consequence of the animals tolerance and current physiological state (Plotkin, 2000). Secondary compounds are increasingly recognized as important in animal health and nutrition, though historically they were thought by agriculturalists and ecologists alike to adversely affect herbivores (Dawson *et al*., 1999). In this paper, we discover emerging information on how secondary compounds in plants with medical properties may directly and/or indirectly help prevent and eliminate different diseases in livestock. We explore how health benefits may be enhanced by understanding the interplay between plant secondary compounds and foraging behavior.

II – Materials and methods

Three herbs with medicinal properties [*Foeniculum vulgare* Mill. (Apiaceae), *Matricaria chamomilla* L. (Asteraceae) and *Achillea millefolium* L. (Asteraceae)] were examined to determine their influence on intake of high-terpene shrubs (*Juniperus phoenicea* L.), one of the most abundant shrub species in Mediterranean maquis plant communities. *Juniperus phoenicea* was fed to goats either with (treatment) or without (control) access to the three above-mentioned herbs with medical properties (fennel, chamomile and yarrow).

The experimental animals (n = 12; mean weight ± SEM = 12.6 ± 1.1 kg) were 4-month-old goats (a mixture of domestic breed crossed with Saanen and Alpine breeds). All experimental animals were raised on the same shrublands and were experienced in grazing on Mediterranean maquis vegetation. Prior to the experiment animals went through a 5-day pre-conditioning period by adding 200 g of barley mixed with 100 g of every shrub used in experiments. Animals were divided into two groups of six animals (control and treatment). In the first set of research, the three separate experiments were conducted, wherein the animals were offered the various diets daily in a 10 day period. At 8:00, in all experiments animals from both groups were fed with 200 g of barley. Shrub leaves and current season's growth (i.e., twigs) were clipped and ground to 1 cm length with a chipper, mixed for uniformity, placed in woven, polyethylene feed sacks, and stored at 4ºC. In the first experiment, we compared intake of *Juniperus phoenicea* alone (control group) with intake of *J. phoenicea* and *Achillea millefolium* (treatment group) offered at the same time in separated feed boxes. Animals in both groups (control and treatment) were offered 200 g of J. *phoenicea* in food boxes from 09:00 to 14:00 h. Animals and food boxes were checked every 30 min and additional J. *phoenicea* biomass was added as needed. Animals in the treatment group also received 200 g *A. millefolium*, divided in four 50 g meals offered at 9:00, 10:15, 11:30, and 12:45 h. The same protocol was used in the following experiments. In the second experiment, the animals in the treatment group were offered *J. phoenicea* and *M. chamomilla*, while control animals were only fed with

J. phoenicea. In the third experiment, the control group of goats was offered *J. phoenicea* alone, while treatment group of goats was fed a *J. phoenicea* and *F. vulgare.* The second experiment was conducted on the same manner as the first one, including 15 days rest for animals and precondition period. In each of the 10-day experiments, goats were offered juniper biomass ad libitum.

In the second set of research, the four consecutive experiments the phylogenetical similar shrubs of the genius *Quercus* offered to the goats in the first experimental group, while the phylogenetical diverse Mediterranean shrubs offered to the goats in the second experimental group. Shrubs were harvested each week from the vicinity of the feeding experiments. Every day before the experiment, sufficient feed was removed from cold storage and offered to the animals. In all experiments both groups of animals were supplemented with barley (200g) at 08:00 hours, then offered the ground shrubs from 08:30 to 14:00 hours. Shrubs were fed in individual boxes to each animal, and the amounts replenished as necessary during the day. Any uneaten amounts were weighed. Trials lasted for 10 days and ran consecutively. Goats in the *Quercus*-group were fed different species of oak (*Quercus*) genus. Goats in the diverse genera-group were fed species that belong to different genera, families, order and subclasses. From the phylogenetic point of view the shrubs species offered to goats in the second group are very heterogeneous and much more phytochemical diverse.

The experimental design for the shrubs fed individually to goats was a completely random design with a separate analysis for each shrub in both experiments. The model included two treatments per experiment, with individual animals nested within treatments, and repeated measures over the 10-days. The total daily amount consumed of each shrub offered was used as the dependent variable in the analysis. Analyses were conducted using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC; Version 9.1 for Windows). All analyses on shrub intake were adjusted for body weight prior to the analysis (g/kg BW).

III – Results and discussion

Average daily intake was much greater when fennel, chamomile and yarrow were included in combination with rich-terpene shrub *Juniperus phoenicea* (Fig. 1). Rather than substituting the more palatable fennel for shrubs, animals continued to eat about the same amount of shrubs biomass while increasing total intake. Thus, fennel holds promise as a supplemental feed for ruminants consuming shrubs with high concentrations of terpenes. What is not known is whether fennel, chamomile and yarrow can ameliorate effects of secondary compounds consumed by livestock and whether their effects are altered by the biochemical complexity of shrubs consumed.

When goats were fed with different Mediterranean shrubs that belong to different species and genera, they ate more foliage than goats fed with different combinations of high-tannin shrubs that belong to different species of the same *Quercus* genus (*Q. pubescens, Q. ilex, Q. cerris and Q. petraea*) (Fig. 2). Based on the higher biological/biochemical diversity of shrubs, goats increased their intake of the phylogenetically more distant shrubs when compared to more related Mediterranean oak species regardless of their nutritional value. These results support hypothesis that goats ate more of the biochemically diverse shrubs than the biochemically similar oak species. Given a choice of two genetically more diverse and more similar shrubs categories offered to goats, we expected a higher preference for biochemically diverse shrubs and these differences increased from the second to the last experiment.

Mediterranean shrubs produce a variety of secondary metabolites that are toxic and deterrent to herbivores (Silanikove *et al*., 1996). These substances are usually assumed to serve as chemical defenses against herbivores in those ecosystems (Rogosic *et al*., 2007), but at appropriate doses can suppress production of the pathogens that can impair herbivore health (Engel, 2002). The difference between a toxin and a medicine is merely a matter of dosage (Plotkin, 2000). Still, we know very

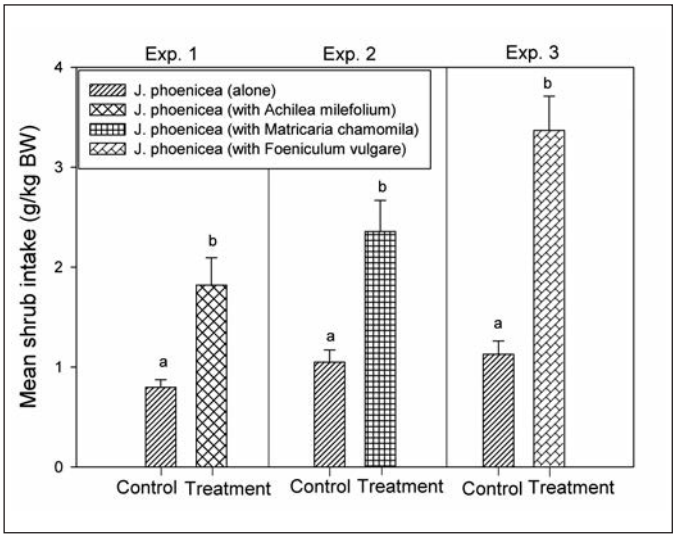

Fig. 1. Intake (g/kg BW) of goats fed different combinations of high-terpene shrub *Juniperus phoenicea* and herbs *Foeniculum vulgare, Matricaria chamomilla* and *Achillea millefolium* with medical properties; n = 6 per treatment group; (*P* < 0.01).

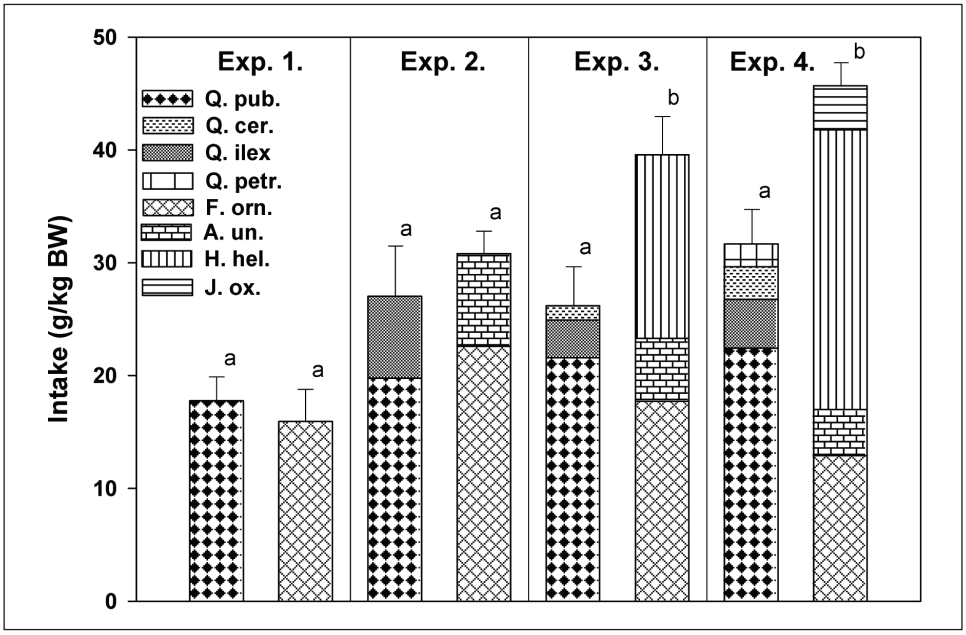

Fig. 2. Total shrubs intake (g/kg BW ± SE) of goats fed different combinations of high-tannin shrubs in group 1 that belong different species of the same *Quercus* genus (*Q. pubescens, Q. ilex, Q. cerris and Q. petraea)* and shrubs in group 2 that belong to different species and different genus (*Fraxinus ornus*, *Arbutus unedo*, *Hedera helix* and *Juniperus oxycedrus*) n = 6 per treatment group; P < 0.01.

little about how herbivores might learn to use secondary compounds for health and medicinal benefits. While much remains to be learned, herbivores can learn to use medicines to attenuate the aversive effects of acidosis as well as tannin and terpene toxicosis (Provenza and Villalba, 2006). They also select diets that (i) provide necessary amounts of energy and protein, (ii) synchronize the supply of energy and protein, (iii) balance supplies of macronutrients and toxins, and (iv) benefit different kinds of complementary toxins (Rogosic *et al*., 2003; 2006). Above mentioned examples show that herbivores differ the main properties and interactions among nutrients, toxins, and medicines.

The relationship between phylogenetic distances implies a greater diversity in plant secondary compounds, and is a key to understanding mechanisms of plant animal interactions in Mediterranean shrubby ecosystems. Secondary metabolites function as a defense against herbivores, so their class, concentrations and diversity determine herbivore preference (Rogosic *et al*., 2007), and therefore have an important role in the plant's survival in natural conditions. Likewise, they represent adaptive characteristics that have been subjected to natural selection during evolution (Rasmann and Anurag, 2011).

IV – Conclusions

According to the results achieved in the experiments presented, natural plant communities like Mediterranean rangelands with diverse mixtures of plant species are literally nutrition centers and pharmacies with vast arrays of primary (nutrient) and secondary (pharmaceutical) compounds vital in the nutrition and health of plants and herbivores. Self-medication has the potential to facilitate the design of sustainable grazing systems to improve the quality of land as well as the health and welfare of animals. Understanding foraging as the dynamic quest to achieve homeostasis will lead to implementing management programs where herbivores have access not only to diverse and nutritious foods but also to arrays of medicinal plants.

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Parallel Session 2
(Mediterranean Pastures Subnetwork)

Promising forage resources for Mediterranean production systems

Promising forage resources for production systems in Mediterranean areas

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Abstract. Extensive livestock production is a basic socio-economic feature of Mediterranean agriculture threatened by overgrazing of natural grasslands and by climate change. Stress-tolerant forage resources are increasingly needed, therefore, to enhance the sustainability of Mediterranean crop-livestock systems. Assessing the response of the available germplasm of a few, key species across different stress levels of the Mediterranean area can provide information on best plant types, genetic resources and adaptation strategies. A large set of experiments (here summarised) was performed for over a decade on both sides of the western Mediterranean basin, indicating that germplasm adapted to dryland conditions can be found in all forage species. This germplasm could be directly used for cropping or as parental material in breeding programmes. A clear genotype × environment interaction was generally found for yield, emphasising the need of selecting specific germplasm for different environments. Legume-based crops displayed higher forage quality and farmers' appreciation than pure-stand crops of cereals or grasses.

Keywords. Adaptation – Drought tolerance – Genotype × environment interaction – Selection – Summer dormancy.

Ressources fourragères pour les systèmes de production des zones méditerranéennes

Résumé. *L'élevage extensif est une caractéristique socio-économique de base de l'agriculture méditerranéenne, menacée par le surpâturage des prairies naturelles et par le changement climatique. Des ressources fourragères tolérantes au stress sont donc de plus en plus nécessaires pour renforcer la durabilité ces systèmes d'élevage. L'évaluation de la réponse du matériel génétique disponible de quelques espèces clés à différents niveaux de stress de la région méditerranéenne peut fournir des informations sur les meilleurs types de plantes, ressources génétiques et stratégies d'adaptation. Un grand nombre d'expériences (résumées ici) a été réalisée pendant plus d'une décennie des deux côtés du bassin méditerranéen occidental, indiquant que du matériel génétique adapté aux conditions de zones sèches peut être trouvé dans toutes les espèces fourragères. Ce matériel génétique pourrait être directement utilisé pour la culture ou comme matériel parental dans les programmes de sélection. Une interaction génotype × environnement a généralement été trouvée pour le rendement, soulignant la nécessité de sélectionner des variétés spécifiques pour différents environnements. Les cultures à base de légumineuses ont montré une meilleure qualité de fourrage et une plus grande satisfaction des agriculteurs que les monocultures de céréales ou de graminées.*

Mots-clés. *Adaptation – Tolérance à la sécheresse – Interaction génotype × environnement – Sélection – Dormance estivale*.

I – Introduction

Crop-livestock systems have an outstanding importance in the Mediterranean basin, safeguarding local economies, protecting the agricultural environment and the rural landscape, fulfilling the steadily growing demand of animal products, and representing an economic buffer for smallholders. The productivity of these systems will be affected by climate change, because of the predicted greater incidence of drought and higher frequency of extreme climatic events. The direct negative effects of climate can be exacerbated by overexploitation of forage resources and increasing costs and/or decreasing availability of irrigation water. Excessive exploitation resulted in decreased feed production and increased erosion and risk of desertification of natural grasslands. To reverse this trend, forage crops able to withstand climatically adverse conditions and provide more feed at sustainable costs are needed. In the drier Mediterranean regions, currently cultivated forages mainly include mixtures or monocultures of annual crops. Annual species display adaptation to severe spring-summer drought thanks to their growth largely concentrated in the cool season, when water is more available, and their ability to survive through the dry period as seeds. Compared to annuals, however, perennial species have quicker regrowth at the onset of autumn rains and better exploit the residual moisture in late spring, thus allowing to extend and regularise the feeding season, mostly concentrated in spring for the annuals. A need arises, therefore, of identifying perennial crops able to persist under Mediterranean climatic conditions. Perennials should possess intrinsic drought tolerance or any physiological mechanism enabling their survival under severe summer drought. Several forage species could be potentially useful for the Mediterranean region. However, as the funding for forage research and breeding in the area is limited at the national and international level (Porqueddu *et al*., 2016a), a careful identification of a few promising species on which concentrating joint efforts and resources is required. Nitrogen-fixing forage and feed legumes with improved tolerance to major abiotic stresses may play a crucial role in strategies of climate change adaptation and mitigation, while enhancing the economic and environmental sustainability of the Mediterranean agriculture. Modelling cultivar responses in multi-site evaluation trials can help appreciating and predicting differences of adaptive patterns across a range of increasingly stressful conditions. Two large international projects on forage crops were carried out involving institutions and researchers from both sides of the Mediterranean Sea. Their major goal was to boost the identification of new and better adapted germplasm across Mediterranean conditions and to offer innovative solutions in livestock feeding and sustainable farming in dryland agriculture. This contribution summarises over a decade of experiments performed in the western Mediterranean basin.

II – Lucerne

Lucerne (*Medicago sativa* L.) is the main forage crop in south-European countries and the main perennial forage species in North Africa. By its deep rooting system, it can tolerate periods of drought. However, in very dry conditions lucerne is only grown under irrigation. Reducing or withholding irrigation during the period of lowest water-use efficiency (summer months) might be a solution deserving verification, provided that suitable germplasm is identified. Soil salinity is a major stress affecting crop production in drought-prone regions of North Africa. A comprehensive study encompassed landrace and variety germplasm from North Africa, southern Europe, Australia and USA and evaluated dry matter (DM) yield over three years across 10 agricultural environments of Algeria, Tunisia, Morocco and Italy, four of which were rainfed, one was continuously irrigated (oasis management) and five were irrigated but with a nine-week irrigation withholding during summer (Annicchiarico *et al*., 2011a). The crop persistence was good in all environments, but the environment mean yield was closely related with the annual and spring-summer (April-September) water available. A yield reduction of about 40% with rainfed cropping was paralleled by a water saving of over 60% compared to the irrigation regime (with summer withholding). The latter had proportional yield reduction and water saving compared to the oasis management. The economic dis-

advantage of lower forage yield might be outweighed by the advantages provided by the saved water with alternative non-agriculture uses or with the irrigation of high-value orchard crops. These results suggested considerable scope for water savings in the Mediterranean basin through rainfed cropping or withheld summer irrigation, provided drought-tolerant germplasm is available.

Crossover genotype × environment (GE) interaction between top-yielding cultivars occurred across the environments. Spring-summer water available, total number of harvests and soil salinity were identified as significant environmental covariates in a factorial regression model explaining over half of the GE interaction variation (Annicchiarico *et al*., 2011a). The old Sardinian cultivar Mamuntanas, which evolved under rainfed cropping and moderate annual rainfall, displayed specific adaptation to severely drought-stressed environments, whereas landraces from North Africa, which evolved in irrigated environments, were generally not adapted to these environments. One variety (Ameristand 801S) and one Moroccan landrace (Erfoud 1) were specifically adapted to salt-stress environments. Apart from saline-soil conditions, the variety SARDI 10 proved to be outstandingly adapted to all conditions. SARDI 10 possibly being an exception, the extent and complexity of the GE interaction effects observed in our study discouraged the breeding of widely adapted varieties across the western Mediterranean basin. To improve our knowledge on the relevant adaptive traits, five cultivars with contrasting adaptive responses were further evaluated under managed environments to identify physiological and morphological traits associated with specific adaptation to drought-stressed and irrigated environments (Annicchiarico *et al*., 2013a). The results emphasised the difficulty of combining traits of environment-specific adaptive value into one widely adapted variety, thus supporting the selection of varieties specifically adapted to contrasting environments.

Based on the multi-site evaluation, a gene pool was established at CREA, Lodi, intercrossing the three outstanding cultivars Mamuntanas, Erfoud 1, and SARDI 10. This gene pool included 152 half-sib progenies and was meant as a common genetic base for phenotypic selection targeted to stress-prone conditions in the Mediterranean basin, with trials established in Lodi, Italy, under severe drought stress (using a rainout shelter), in Alger (Algeria) under rainfed conditions, in Marrakech (Morocco) under summer suspended irrigation, and in Médenine (south Tunisia) under continuous irrigation with saline water (EC_e: 9.73 dS/m). In each location the top 10% progenies were identified based both on cumulated DM yield over three growing seasons and final persistence, to be intercrossed and advanced in the selection process. The phenotypic advantage of the promising progenies over the whole set of material was outstanding in all sites for DM yield and sizeable for the final persistence, except in Marrakesh, where plant survival was sustained by the rather favourable moisture conditions (Table 1).

Table 1. Mean values of cumulated dry-matter yield (DMY) and final persistence of the top 10% lucerne progenies identified in each of four evaluation environments in comparison with the overall trial mean values

Germplasm group	Marrakesh		Alger		Médenine		Lodi (managed stress)	
	DMY (t/ha)	Final persist.	DMY (t/ha)	Final persist.	DMY (t/ha)	Final persist.	DMY (t/ha)	Final persist.
Top 10%	46.52	91.1	25.67	53.6	91.17	19.8	18.67	35.9
Trial mean	37.31	88.6	20.78	47.5	73.64	16.7	13.90	25.8
Difference	+24.7%	+2.8%	+23.5%	+12.8%	+23.8%	+18.6%	+34.3%	+39.1%

III – Cocksfoot

Lucerne can also be grown in mixed stand with a forage grass to improve the crop yield, quality and seasonal distribution, and the efficiency of nitrogen utilisation. Cocksfoot (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) are the most important perennial grass species of potential interest across the Mediterranean basin. Within the Mediterranean germplasm of cocksfoot, two contrasting strategies of adaptation to drought can be found. One strategy relies on summer dormancy, that is, a complete aerial senescence at the end of spring irrespective of the water availability (Volaire *et al*., 2009). This mechanism is mostly found in North-African germplasm of *D. glomerata* subsp. *hispanica* (Roth) Nyman and is especially useful for plant survival under severe stress. Incomplete dormancy can be found in Mediterranean populations of cocksfoot (Volaire *et al*., 2009). The other adaptation strategy is dehydration tolerance, by which enough moisture is maintained in leaf basal tissues even at low soil water potential (Volaire, 2008).

Our main study on cocksfoot involved three rainfed test sites in southern Europe (one each in Italy, France and Portugal) and three in North Africa (one in Morocco and two in Algeria) and encompassed diversified germplasm, of Mediterranean or continental type, and with complete, incomplete or absent summer dormancy (Annicchiarico *et al*., 2011b). The best predictive model for yield was a factorial regression as a function of the site (April-September) drought stress (estimated as long-term potential evapotranspiration minus the actual water available for the crop). The large genotype × location (GL) interaction observed for yield was mostly associated with the summer dormancy trait. Completely dormant germplasm was specifically adapted to the most severe stress, whereas the Mediterranean subsp. *glomerata* germplasm tended to be specifically adapted to moderate drought, although some variation was present in their response to drought stress levels. The continental germplasm was not adapted anywhere. The completely summer-dormant cultivar Kasbah had the highest final persistence across sites, highlighting an intrinsic advantage for this physiological trait in terms of general persistence across environments (possibly conferred by a reduced metabolic activity in summer), in addition to its specific-adaptation effect leading to relatively better yield under severe stress. Should long sward duration be required in severely drought-prone, extensive farming systems, the completely dormant germplasm of subsp. *hispanica* could be a useful plant type for introduction into cultivation or for breeding. When the growing conditions are less stressful, the Mediterranean germplasm of subsp. *glomerata* is a better option than the completely dormant material owing to its higher forage yield potential.

IV – Tall fescue

Two geographical types are recognised in tall fescue, of which the so-called Mediterranean type showed good persistence under summer drought stress (Pecetti *et al.*, 2007). Complete summer dormancy was not reported in the species, but an incomplete dormancy was observed in some Mediterranean tall fescues (Norton *et al*., 2008). Other Mediterranean germplasm relies on dehydration delay related with water uptake from deep roots (Lelièvre *et al*., 2011), although mechanisms of dehydration tolerance should not be overlooked (Norton *et al*., 2006).

We evaluated Mediterranean germplasm of tall fescue for DM yield over three years and final persistence under rainfed conditions across the six rainfed sites previously described for the cocksfoot study (Pecetti *et al*., 2011). The cultivar yield response across sites was best predicted by a factorial regression as a function of the site spring-summer (April-September) drought stress. The yield potential also proved to be restricted by cold winter temperatures. The incompletely-dormant varieties Flecha and Fraydo showed positive adaptation to sites with highest spring-summer drought stress. Their adaptation pattern was consistent with the higher level of drought stress of their selection environments compared to the other tested cultivars. Although crossover GL interaction was remarkable in this study,

Flecha tended towards wide adaptation across sites. This pattern suggested that selection of tall fescue germplasm with wide adaptation across diversified Mediterranean drought stress levels can be feasible, unlike in cocksfoot where specific-adaptation responses were remarkable and largely accounted for by the presence of the complete summer dormancy mechanism.

When directly compared, Mediterranean tall fescue consistently outyielded Mediterranean cocksfoot (Pecetti *et al*., 2009; Lelièvre *et al*., 2011; Annicchiarico *et al*., 2013b). This yield advantage of tall fescue may derive from higher water-use efficiency and greater growth across autumn and winter, as well as deeper and larger root system compared to cocksfoot (*Lelièvre et al*., 2011). In this sense, tall fescue appears to meet the desirable ideotype for a perennial species, which is provided with endurance to summer drought coupled with high growth rate when moisture availability is non limiting.

V – Pea

Pea (*Pisum sativum* L.) is the main feed grain legume along with faba bean (*Vicia faba* L.) in southern Europe, while it is mostly grown for forage in mixture with a cereal in the Maghreb. Pea has a remarkable flexibility of use, as it may be harvested at crop maturity for grain (used as a concentrate) and straw (used as a fodder, with nutritive value slightly lower than that of an average lucerne hay) or harvested earlier for hay production. If unfavourable climatic conditions led to poor grain yield, it may also be grazed at maturity. Elite plant material was identified and used to produce sets of recombinant inbred lines (RIL) for breeding purposes (Annicchiarico and Iannucci, 2008). Seed of three paired crosses between the promising varieties Attika, Isard and Kaspa was multiplied at CREA, Lodi, and made available for the phenotypic evaluation. For each *cross*, a set of about 100 RILs was evaluated in three experiments carried out in Lodi (Italy) under severe terminal drought (under a rainout shelter), Alger (Algeria) under rainfed conditions and moderate drought stress, and Marchouch (Morocco) under rainfed conditions and severe stress. Both in Marchouch and Alger, the aim was to identify the three best grain yielding lines within each cross, to be advanced to the next selection steps. The yield advantage (in phenotypic terms) of the preliminarily selected germplasm over the entire set of evaluated lines and the parent cultivars was outstanding (Table 2). The selection requirements for a pea variety in Italy entailed additional factors than just adaptation to severe terminal drought, although this is a situation often experienced in harsh Mediterranean areas of southern Italy. The recorded data highlighted the positive features of four lines, out of which one new variety adapted to Italian conditions was proposed for registration.

Table 2. Grain yield mean values of preliminarily selected pea lines (three lines within each cross: Attika x Isard; Kaspa x Attika; Kaspa x Isard) from the evaluation under rainfed conditions in Marchouch, Morocco, and Alger, Algeria, of 315 lines from three crosses, and grain yield mean values of the whole set of lines

Germplasm group	Marchouch, severe drought (56 mm rainfall)	Alger, moderate drought (348 mm rainfall)
	Grain yield (t/ha)	Grain yield (t/ha)
Selected lines	0.84	2.68
Trial mean	0.36	1.37
Difference	+133%	+95%

VI – Legume-based forage mixtures

We aimed at optimising the cultivation and use of pea-based and lucerne-based forage crops in different drought-prone Mediterranean environments, by assessing different pea-cereal and lucerne-grass mixtures, other mixtures with legume species, and pure-stand crops, in terms of forage yielding ability, resilience, forage quality and acceptability by farmers. Legume-based mixtures raise potential interest to increase crop forage yield and/or quality through resource complementarity of different species, but their actual performance and acceptability by farmers need to be verified. Key questions need to be solved to design and propose innovative forage crops, such as: Choosing annual or perennial crops? Growing legumes in pure stand or in mixture with cereals/grasses? Growing binary or more complex mixtures? Is there more suitable legume crop ideotypes (e.g., in terms of plant morphology) than others to grow in mixtures? A study was carried out across the drought-prone Mediterranean sites of Sassari, Sardinia, Marchouch, inland Morocco, and Sétif, inland Algeria. The experiment included 16 annual and 9 perennial forage crops, encompassing pure and mixed stands of annual legumes (pea, common vetch, Narbon vetch), cereals (oat and triticale), lucerne and grasses (cocksfoot and tall fescue) (Annicchiarico *et al*., 2017a; 2017b). A tall and a semi-dwarf pea line (the plant stature depending on the presence or absence of dwarfing genes) and an upright growing and a semi-erect lucerne population were evaluated as possible plant ideotype alternatives. All combinations of legume-cereal binary mixtures and two complex (4-components) mixtures (one with two pea types and two cereals; the other with two vetch species and two cereals) were evaluated for annual crops, while perennial mixtures included each lucerne type associated with each grass species and a complex (4-component) mixture with both lucerne types and both grass species. Perennials were only evaluated in Sassari and Marchouch. Annuals were harvested once in spring with legumes at early pod-filling and cereals at heading stage. Results of annual crops across three sites and two evaluation seasons are summarised in Table 3.

Table 3. Mean values of crop dry-matter yield (DMY), weed proportion on total dry biomass, legume proportion on crop DMY, land equivalent ratio (LER), and visual appraisal score (scale 1-5) attributed by local farmers, for different forage crops across two growing seasons in three Mediterranean sites (farmers' score from only two sites). Cereal data in PS and BM are the averages of crops including oat or triticale. Elaboration from Annicchiarico *et al.* (2017a)

Crop	DMY crop (t/ha)	Weed %	Legume %	LER	Farmers' score
PS – Cereal	6.26	6.7	–	–	3.50
PS – Tall pea	5.85	8.6	–	–	3.76
PS – Semi-dwarf pea	5.29	12.9	–	–	4.39
PS – Common vetch	3.82	12.9	–	–	3.60
BM – Cereal + tall pea	6.23	7.2	40.4	1.03	3.93
BM – Cereal + semi-dwarf pea	5.60	9.2	32.9	0.97	4.03
BM – Cereal + common vetch	5.56	5.6	33.2	1.02	4.01
CM – 2 cereals + 2 pea types	5.45	7.1	37.3	0.92	3.57

PS: pure stand; BM: binary mixture; CM: complex mixture.

The tall pea line showed the greatest competitive ability versus the cereals and maximised the yield and legume proportion of legume-cereal crops (being significantly superior to the semi-dwarf pea line). Vetch-cereal binary mixtures had lower weed content than the average of the component pure stands. Cereal pure stands (particularly oat) were top yielding but modestly appreciated by farmers. Pea monocultures combined good yielding ability, competition against weeds and farmers' appreciation. The latter trait, however, was very site specific, suggesting that other factors besides crop productivity and competitive ability influenced the farmer perception of the crop value. Farmers in Sassari, for instance, tended to give greater appreciation to the widely known common vetch-

based crops, while crops including the semi-dwarf pea line were praised more as a potential grain crop than as a forage crop, and the fear of possible difficulties in the harvest penalised the tall pea line despite its good performance. No differences among crops were found for the Land Equivalent Ratio (LER) of mixtures. Cereal-tall pea and cereal-common vetch binary mixtures had LER values above the unit, indicating a mild, but positive, effect of species complementarity compared to the respective pure stands.

Forage quality of binary and complex mixtures of annual crops was assessed over two growing seasons in Sassari (Porqueddu *et al*., 2016b). The common vetch-based binary mixtures had higher protein content than the pea-based binary or complex mixtures, whereas no differences were observed for NDF, ADF or digestible dry matter (DDM). NDF and ADF values allowed to classify all mixtures as good (NDF < 500 g/kg; ADF < 310 g/kg). DDM was quite good in all mixtures ranging on average from 616 to 632 g/kg across mixtures. Triticale was invariably less competing than oat in mixtures, resulting in a positive effect on the forage quality of its binary mixtures in terms of protein, digestibility and fibre, regardless of the companion legume.

For perennials, DM production was mostly concentrated in spring in Morocco (5 cuts across three years), whereas the crops produced throughout the years in Sardinia (11 cuts) but with lower yield. The cumulated DM yield of perennials averaged across the two evaluation sites showed that the erect lucerne cultivar Mamuntanas (alias Surigheddu) in pure stand yielded 127% more forage, and the semi-erect type 53% more forage than the mean of the two grass pure stands (the adapted cultivars Flecha and Kasbah). The lucerne-grass binary mixtures did not increase the DM yield compared to the respective lucerne pure stands. The complex mixture outyielded the pure stand and binary mixtures of the semi-erect lucerne (+42%) but not those of the erect lucerne variety. Consistent with the productive results, lucerne in pure stand displayed greater farmers' acceptability than lucerne-grass mixtures.

The reported comparison between annuals and perennials in the same location and the same period (Annicchiarico *et al*., 2017b) indicated that annual crops outyielded perennials (6.35 *vs* 5.14 t/ha) and were more competitive against weeds (3% *vs* 26% weed proportion, respectively). However, the DM yield of the perennial complex mixture was as high as that of the best annual crops. On average, the proportion of legumes in mixtures was high both in annuals (40%) and perennials (53%). The advantage of mixtures over pure stands was much greater for perennials than for annuals in terms of LER (1.31 *vs* 1.03). As the yield efficiency of a mixture, hence its LER, is mainly determined by the performance of its weaker component, the low yield potential of the grass pure stands accounted for such a relative advantage of mixtures in perennials.

VII – Conclusions

The large set of experiments performed for almost 15 years in the western Mediterranean basin provided evidence that germplasm adapted to dryland conditions can be found in all main forage species. These genetic resources could be exploited for direct introduction into cropping or as useful parental material in breeding programmes. With the possible exception of the best tall fescue germplasm, in all other species outstanding genotype × environment interaction (with inconsistent cultivar ranking across environments) was found for yield, reinforcing the need for selecting specific varieties for each sub-region. Specific selections in the main species are on their way or produced already candidate varieties. The more or less direct interface between the research and the productive world that the long period of experimentation enabled brought to attention a very important practical hindrance to the adoption of novel, adapted forage crops, that is, the general weakness of the forage seed chain in the Mediterranean region.

A key outcome of this activity is that legume-based crops displayed higher forage quality and farmers' appreciation than pure-stand crops of cereals or grasses. Pea showed much greater potential as a forage crop for Mediterranean environments than hitherto believed, both in pure stand and in intercropping. Common vetch was about as valuable as pea for mixed cropping. Lucerne mixtures with grasses were high yielding, but pure stands of adapted germplasm yielded as much and were appreciated by farmers. Complex mixtures did not provide a clear advantage over binary mixtures. In general, the best annual crops tended to be higher yielding than the best perennials and may be preferable for hay production. However, perennials offer the advantage of extended herbage production, particularly in less stressed environments.

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Performance of local populations of *Medicago truncatula, M. laciniata* and *M. minima* collected in the Algerian steppe areas

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Abstract. As part of the development of local species to be used in pastures and in crop-livestock systems in Algeria, twelve populations of *Medicago truncatula, M. laciniata* and *M.* minima were evaluated for their forage and grain yield during 2016/2017 cropping season. The study focused on dry matter yield and pod and seed production. A randomized block design with three replications was used. The results obtained show that the populations of the three species tested differ significantly for all measured variables. The study identified populations with high dry matter and seed yields. The Principal Component Analysis clearly discriminated the populations of *M. minima, M. laciniata* and *M. truncatula*. We noted that early populations of *M. truncatula* had the highest of pods and seeds yield.

Key words. *Medicago truncatula* – *M. laciniata*– *M. minima* – Seed yield – Forage yield.

Performance de populations locales de* Medicago truncatula, M. laciniata *et* M. minima *collectées dans les zones steppiques Algériennes

Résumé. *Dans le cadre du développement des espèces locales à exploiter en pâturages et dans les systèmes de culture-élevage en Algérie, douze populations de* Medicago truncatula, M. laciniata *et M*. minima *ont été évaluées pour leur rendement fourrager et leur rendement en graine au cours de la compagne agricole 2016/2017. L'étude a porté sur la lez rendement en matière sèche et la production en gousses et en graines. Le dispositif expérimental utilisé est un bloc complètement randomisé avec trois répétitions. Les résultats obtenus montrent que les populations des trois espèces testées diffèrent significativement pour l'ensemble des variables mesurées. L'étude a identifié des populations présentant un bon rendement en matière sèche et en graines. L'analyse en composantes principales a clairement différencié les populations de* M. minima, M. laciniata *et* M. truncatula*. Nous avons également noté que les premières populations avaient le rendement le plus élevé en gousses et en graines. Nous avons noté que les populations précoces de M. truncatula ont enregistré les meilleurs rendements en gousses et en graines.*

Mots-clés. Medicago truncatula – M. laciniata – M. minima – *Rendement en grains – Rendement fourrager.*

I – Introduction

Among crops reliable to promote pastoral zones that produce forage and restore destroyed pasture land especially in arid and semi-arid areas, the genus *Medicago* L. (Fabaceae) constitutes an important genetic resource (Haddioui *et al*., 2012). Annual species are found in all bioclimatic zones from wet area to the Sahara. Some have a wide spectrum of distribution; others have limited distribution area (Abdelkefi and Marrakchi, 2000).

Medics are excellent candidates for pastures and cover crops in sustainable agriculture systems, such as pastures and cover crops (Dorry, 2010). Their high levels of hard seededness makes them well adapted to ley farming systems and to persistence in regions of unreliable rainfall (Nichols *et al*., 2007).

With others annual legumes, medics are mainly the base of agropastoral systems. They show a high potential for seed and forage production, and self regeneration ability (Porqueddu and Gonzalez, 2006).

The objective of the present work is to evaluate forage yield and seed production of twelve local populations of *Medicago truncatula*, *M.laciniata* and *M. minima*.

II – Materials and methods

Twelve local populations of *Medicago truncatula, M. laciniata* and *M. minima* collected in different sites of Djelfa area by the National Institute of Agronomic Research of Algeria (INRAA) in 2008 were used (Table 1). The trial was conducted during the 2016/2017 cropping season at the experimental farm of the Research station of Baraki, Algiers (INRAA). Populations were sown on 22 December 2016 at a density of 100 scarified seeds/ row of 1 m long spaced by 1.5 m. A randomized block design with 3 replications was used. At flowering period, the rows were mown and aerial biomass (AB, g) and dry matter yield (DMY, g) were measured. Dry matter was determined after drying a sample in a forced air oven at 65°C during 48 hours. Total number of pods (TNP), pod weight (PW, g), total number of seeds (TNS) and seed weight (SW, g) were measured after harvest.

The collected data were subjected to an analysis of variance (ANOVA) using the GenStat software edition 12 and the measured traits means were compared between populations with Least Significant Difference (LSD) test at 5% probability level. Principal components analysis (PCA) was performed to establish the importance of different traits in explaining multivariate polymorphisms, using Statistica 6.0 software. Relationships among measured traits were tested using Pearson correlation coefficients.

Table 1. List of populations of *Medicago truncatula, M. laciniata* and *M. minima* populations and their original collection sites

Species	Geographical Origin	Altitude (m)
Medicago minima	Ain Oussera **(MmAO)**	758
	Mliliha **(MmMli)**	806
	Charef **(MmCh)**	960
	Oued Touil **(MmOT)**	718
Medicago laciniata	Bouiret Lahdab **(MlBL)**	830
	Messaad **(MlMes)**	950
	Mliliha **(MlMli)**	806
	Oued Touil **(MmOT)**	718
Medicago truncatula	Charef **(MtCh)**	960
	Mliliha **(MtMli)**	806
	Ain Oussera **(MtAO)**	758
	Oued Touil **(MtOT)**	718

III – Results and discussion

Means and range of variation of the measured traits are given in Table 2. The variance analysis showed significant to highly significant differences between populations. The flowering date varied from 86 to 98 days after emergence. The *M. truncatula* populations from Oued Touil and Ain Oussera were the earliest ones with 86 calendar days, while the *M. minima* population from Charef region was the latest (98 days). Populations of *M. truncatula* were earlier than those of *M. laciniata* and *M. minima*. In Sicilian *M. polymorpha* populations, the flowering time ranged from 110 to 128 days (Graziano *et al.,* 2010). According to Del Pozo and Aronson (2000), annual legumes show both ecotypic differentiation and a high degree of plasticity in flowering time. For forage production, the most productive population was Oued Touil for *M. truncatula* with 1997 g for aerial biomass and 340 g

for dry matter yield. While population of *M. minima* from Mliliha had the lowest biomass and dry matter (768 g and 120.3 g, respectively). Graziano *et al.* (2010) reported large differences among Sicilian populations for DM yield at spring cut (231-655 g/m² with an average of 443 g/m²). According to Porqueddu and Gonzalez (2006), forage yields depend upon the specific growing conditions, but especially rainfall during the growing season. The tested populations of the three species differed significantly for pod and seed production. The highest pod and seed yields were recorded by the two populations of *M. truncatula* from Charef and Ain Oussera (477.7 g and 119.8 g respectively). While, the highest pod and seed numbers were obtained by the population of *M. minima* from Charef (with respectively 14867 and 74928 seeds) as reported by Chebouti *et al.* (2015).

Table 2. Mean and values of the measured traits in *M. minima, M. laciniata* and *M. truncatula* populations

Populations/traits	FT (days)	AB (g)	DMY (g)	TNP	PW (g)	TNS	SW (g)
MlBL	95^{b}	1199^{bcd}	302^{abc}	5100^{ef}	78.2^{f}	31200^{ef}	64^{efg}
MlMes	95^{b}	1407^{abc}	292^{abc}	3500^{f}	79.2^{f}	17500^{g}	45.5^{g}
MlMli	88^{c}	1418^{abc}	300^{abc}	8457^{cd}	196.9^{e}	49391^{cd}	84^{cd}
MlOT	88^{c}	787^{d}	164^{de}	10443^{bc}	223.4^{de}	57215^{bc}	107.7^{ab}
MmAO	95^{b}	1322^{abc}	322^{ab}	6885^{de}	307.1^{c}	39964^{de}	67.8^{def}
MmCh	98^{a}	1012^{abc}	183^{cde}	14867^{a}	237.5^{de}	74928^{a}	95.1^{bc}
MmMli	96^{b}	768^{d}	120^{e}	11206^{b}	258.5^{cde}	60959^{b}	82.5^{cde}
MmOT	88^{c}	1077^{abc}	220^{bcde}	10296^{bc}	282.9^{cd}	51510^{bc}	59.2^{fg}
MtAO	86^{d}	1305^{bcd}	243^{abcd}	8861^{cd}	407.2^{b}	40759^{de}	119.8^{a}
MtCh	88^{c}	1495^{ab}	302^{abc}	7663^{d}	477.7^{a}	33412^{ef}	90.9^{bc}
MtMli	88^{c}	877^{cd}	168^{de}	4221^{f}	256.8^{cde}	23404^{fg}	65.8^{def}
MtOT	86^{d}	1997^{a}	340^{a}	4667^{f}	279.3^{cd}	28315^{f}	79.8^{cde}
Lsd	1.466	600.9	120.3	1992.0	64.6	10255.1	19.4
Sign.	***	*	**	***	***	***	***

Lsd: Least significant difference, FT: Flowering time, AB: aerial biomass per line, Pod formation time, DMY: Dry matter yield per line, TNP: Total number of pods per line, PW: Pods weight per line, TNS: Total number of seeds, SW: Seed weight per line.

Correlation coefficients are given in Table 3. Populations with high biomass had high dry matter yield (r = 0.885***). Dry matter yield was negatively correlated with total number of pods (r = –0.579*) and with total number of seeds (r = –0.578*). Total number of pods and seeds were closely related and vary in similar ways (r = 0.973***). Populations that recorded high seed yield had the highest pods and seeds number. Cocks (1988) indicted that seed yield was closely related to number of pods in all ecotypes of annual *Medicago* sp. In many legumes, pod number is one of the most effective factor on seed yield is pod number and commonly there is a linear function between pod number and seed yield (Bagheri *et al*., 2010). Nevertheless, no relationships were observed between flowering time and the rest of the traits.

The principal component analysis identified two principal components, which together accounted for 76.21% of the total variation (Figure 1). The component 1explained 47.47% of the variation and was positively influenced by aerial biomass and dry matter yield and negatively by totals numbers of pods and seeds. The second component explained 28.74% of the variation, it is positively correlated with flowering time and negatively with pod and seed weight (Figure 1). In fact, populations from Ain Oueesra and Oued Touil of *M. minima* and *M. truncatula*, respectively, from the positive side of the PC1, are characterized by high biomass and high dry matter yield. They oppose on the negative side of PC1, populations of *M. minima* from Mliliha, Charef and Oued Toui Regions and that of *M. laciniata* from Oued Touil, which have the highest pod and seed numbers. Populations of *M. truncatula* from Ain Oussera and Charef, plotted on the negative side of PC2, were the earliest ones and have high pod and seed yields. They opposed populations of *M. laciniata* from Messaad and of *M. truncatula* from Mliliha which have the lowest pod and seed yields.

Table 3. Relationships among measured traits in *M. truncatula, M. laciniata* and *M. minima* populations

	FT	AB	MDY	TNP	PW	TNS	SW
FT	1.00						
AB	-0.328	1.00					
MDY	-0.163	**0.885*** **	1.00				
TNP	0.237	-0.492	**-0.579***	1.00			
PW	-0.479	0.156	-0.005	0.251	1.00		
TNS	0.285	-0.510	**-0.578***	**0.973*** **	0.116	1.00	
SW	-0.340	-0.107	-0.269	**0.585***	**0.576***	**0.601***	1.00

Significant levels, *< 0.05, **< 0.01 and ***< 0.001.

FT: Flowering time, AB: aerial biomass per line, Pod formation time, DMY: Dry matter yield per line, TNP: Total number of pods per line, PW: Pods weight per line, TNS: Total number of seeds, SW: Seed weight per line.

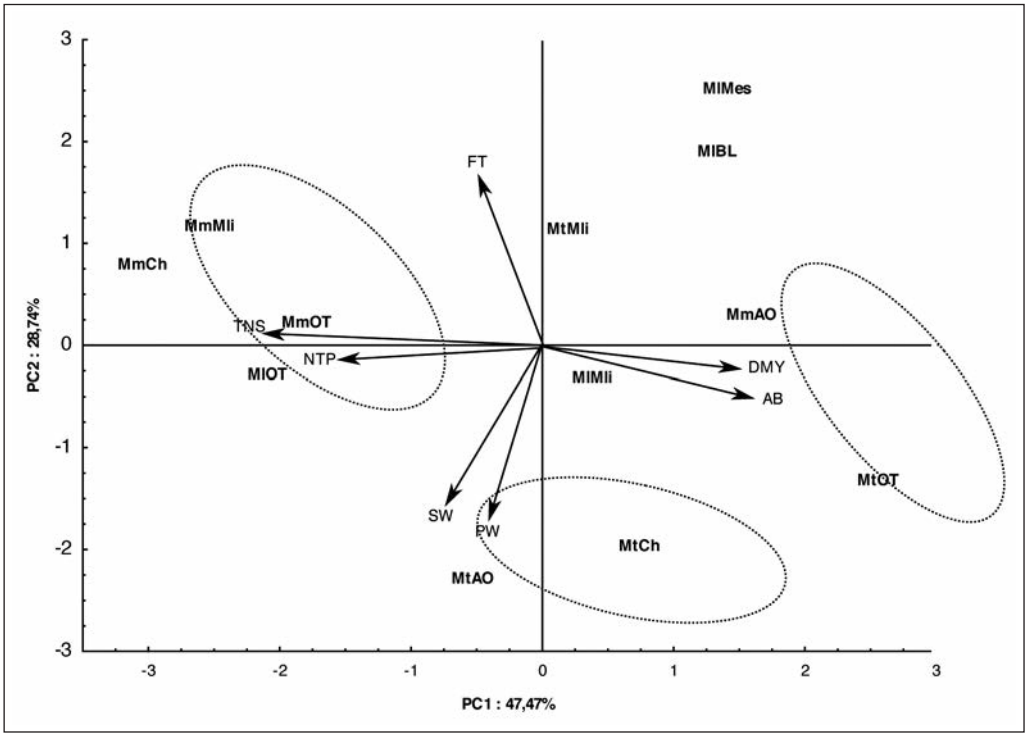

Fig. 1. The Biplot of Principal Component Analysis (PCA) performed on traits and populations of *M. truncatula, M. laciniata* and *M. minima.*

IV – Conclusions

In conclusion, we noted a large differentiation between local populations of *M. minima, M. laciniata* and *M. truncatula* for the most of agronomic traits. From these results, several populations of *M. truncatula* and *M. minima* were selected with regard to their high pods and seeds production and high dry matter yield. They will be exploited in pastures in order to improve forage production in Algeria.

From the PCA, populations from Oued Touil and Ain Oussera of *M. truncatula* and *M. minima*, respectively selected for their performance on dry matter and seed yield as well as their aerial bio-

mass. Also, the *M. minima* populations from Charef, Mliliha and Oued Touil regions as well as the *M. laciniata* population from Oued Touil were selected for their high pod and seed numbers and the *M. truncatula* populations from Ain Oussera and Charef regions as the most performant populations for their seeds yields.

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Influence of altitude and seasons on forage quality of *Prosopis juliflora* shrubs

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Abstract. Fodder trees and shrubs in low rainfall areas are considered as an important source of feed adapted to harsh environments and overgrazing. A study was carried out to evaluate the quality indices of *Prosopis juliflora* forage shrub harvested in two growing seasons (spring and autumn 2013-2014) at three locations (Makkah, Jeddah, and Taif) in Kingdom of Saudi Arabia with varied altitudes. Forage harvested in spring had higher crude protein content but low crude fiber. The highest crude protein (CP) was found in forage growing in Taif (14.6%) characterized by high moisture availability and high altitude. In general, the values of ADF and NDF were relatively low and ranged from 26-42%. Forage harvested from Taif, had less NDF and ADF than that harvested from the other two locations. Nitrogen free extract (NFE) which represents the amount of carbohydrates in forage was higher in spring than in autumn. Calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg), total digestible nutrients (TDN), digestible energy (DE), metabolized energy (ME) and net energy (NE) were not affected by seasons or sites or their interaction?

Keywords. *Prosopis juliflora* – Forage quality – Chemical composition – Seasonal variation – Saudi Arabia.

***Influence de l'altitude et des saisons sur la qualité fourragère des arbustes* Prosopis juliflora**

Résumé. *Les arbres et les arbustes fourragers dans les zones à faible pluviosité sont considérés comme une source d'alimentation importante grâce à leur adaptation aux environnements difficiles et au surpâturage. Une étude a été réalisée pour évaluer la qualité d'arbustes fourragers de* Prosopis juliflora *récoltés à deux saisons de croissance (printemps et automne 2013-2014) dans trois localités d'altitude variable en Arabie saoudite (La Mecque, Djeddah et Taëf). Les fourrages récoltés au printemps ont une teneur élevée en protéines brutes (PB) mais des teneurs faibles en fibres brutes (FB). La plus forte teneur en protéines brutes (PB) a été trouvée dans les fourrages cultivés à Taif (14,6%), un endroit plus humide à altitude élevée. En général, les valeurs d'ADF et de NDF étaient relativement faibles et varient de 26 à 42%. Les fourrages récoltés à Taif, endroit plus humide que Makkah et Jeddah, ont moins de NDF et d'ADF que les fourrages cultivés dans les autres localités. L'extrait sans azote (ESA), qui représente la quantité de glucides dans le fourrage, était plus élevé au printemps qu'en automne. Le calcium (Ca), le phosphore (P), le potassium (K), le magnésium (Mg), les nutriments totaux digestibles (TDN), l'énergie digestible (DE), l'énergie métabolisée (ME) et l'énergie nette (NE) ne sont affectés ni par la saison, ni par la localité ni par leur interaction.*

Mots-clés. Prosopis juliflora – *Qualité fourragère – Composition chimique – Saison – Arabie Saoudite.*

I – Introduction

Kingdom of Saudi Arabia (KSA) (Lat: 32' 34º N – 16' 83º N, long. 34' 36ºE – 56'E) is a vast arid desert with a total area of about 2.25 millions km^2 covering the major part of the Arabian Peninsula. Xerophytic vegetation makes up the prominent features of the plant life in the Kingdom (Zahran, 1982).

Legume fodder trees and shrubs, in the low rainfall areas, especially in arid and hyper arid areas, are adapted to stressful environments which frequently subjected to water shortage, overgrazing, coppicing and rehabilitation of rangelands. In addition, deep-rooted shrubs promote more efficient

water use and year-round ground cover compared with annual crops and pastures and also provide extra shade and shelter for livestock (Harris, 2010; Koech *et al*., 2010). *Prosopis juliflora* (prosopis or mesquite) is a shrub or small tree belonging to Fabaceae family (Leguminosae), and is one of phreatophytes plants, which are supplied with surface water and often have their roots constantly in touch with soil moisture. *Prosopis juliflora* leaves and fruits can be considered as potential source of protein, especially when herbaceous vegetation becomes withered during droughts.

Seasonal forage quality is an important consideration when planning rangelands rehabilitation. Seasonal variations affect the availability of nutrients from the soil to the plant. The nutritional values of forage species are generally low in dry seasons compared with wet season (Onyeonagu and Eze, 2013). Environmental factors such as temperature, precipitation, altitude, etc. may strongly influence forage yield and quality (Kwon *et al*., 2005). Estimates of forage quality constituents, including crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF), can be used to predict animals' performance (Jacobs, 2012).

The objective of this study was to investigate the foliage quality (nutritive value) of *Prosopis juliflora* as affected by three growing sites (with different elevations) and two harvesting seasons (spring and autumn) in Kingdom of Saudi Arabia.

II – Materials and methods

Study area, The study was conducted at three selected sites at Kingdom of Saudi Arabia: Holy Makkah (Mecca), located in the south-west of KSA (21° 25' 19'' N, 39° 49' 46'' E) where plant samples were taken from Arafat area at an altitude of f 238m above sea level; Jeddah, located in the west coast of the KSA (21° 32' 36'' N, 39° 10' 22'' E) and plant samples were taken from Jeddah – Makkah road (15 Km from Jeddah) at an elevation of 74 m above sea level and the Taif region, situated in the mountains above Makkah and Jeddah on the eastern slopes of the Al-Sarawat Mountains (21° 26' N, 40° 21' E) and lies south east of Jeddah and Makkah. The plant samples were taken from Al-Hadda -Taif road at an elevation of 1840 m above sea level. The climate of the tested sites is reported in Table 1. Soil samples were collected from the three selected sites at a depth of 0–60 cm. Physical and chemical soil analysis are given in Table 2.

Table 1. Long term climatic data (1980-2015) of Makkah, Jeddah and Taif experimental sites

Site	Avg high temp. (°C)	Avg. low temp. (°C)	Rainfall (mm)	Humidity (%)
Makkah	37.93	24.55	110.1	46.4
Jeddah	33.55	22.98	53.5	62.75
Taif	29.06	15.73	119.0	41.08

Source: National Oceanic and Atmospheric Administration (NOAA), USA.

Table 2. Physical and chemical soil analysis of the experimental sites (Makkah, Jeddah and Taif). (N and P expressed in ppm; anions and cations expressed in mg l^{-1})

Sites	Particle-size distribution (%)				Soil texture
	Coarse Sand (1 - 0.5)	Fine Sand (0.25-0.1)	Silt (0.05-0.002)	Clay (0.002)	
Makkah	46.70	33.85	10.34	9.11	Sandy loam
Jeddah	35.30	60.13	0.90	3.67	Sandy
Taif	12.64	43.42	27.34	16.60	Sandy loam

Sites	pH	N	P	$CaCO_3$	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
Makkah	8.30	25.00	10.00	1.00	1.00	0.55	0.27	1.00	0.20	0.42	0.20
Jeddah	8.10	30.00	24.00	2.60	1.60	0.90	0.20	1.60	0.20	0.77	0.13
Taif	7.60	60.00	26.00	0.20	2.60	2.00	2.80	4.60	0.10	2.64	0.16

Plant new growth was collected in autumn (September 2013) and spring (April 2014) in all three sites. Samples were dried in an air oven at 65°C till a constant weight and ground to powder for chemical analysis. Crude protein (CP), crude fiber (CF), ash content (Ash) and ether extract (EE) was determined according to A.O.A.C. (2005). Nitrogen free extract content (NFE) was calculated according to the following equation: NFE (%) = 100 – (Ash% + CP% + CF% + EE% on DM basis)

Potassium (K) and calcium (Ca) were detected by using Flame photometer, while magnesium (Mg) was determined by atomic absorption, and phosphorus (P) by spectrophotometer. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the procedure described by Goering and Van Soest (1970). Total digestible nutrients (TDN) were estimated by following equation (Abou El-Naga and El-Shazly, 1971): TDN (% DM) = 0.623 (100 +1.25 EE) - 0.72 CP, where EE is ether extract (%) and CP is crude protein (%).

Gross energy (GE) was calculated by following equation (NRS, 1984): GE (kcal 100 g_{-1}) = 5.72 CP% + 9.5 EE% +4.79 CF% +4.03 NFE%. Digestible energy (DE) was calculated by the equation (NRS, 1984): DE (Mcal kg^{-1}) = 0.0504 CP% + 0.077 EE% + 0.02 CF% + 0.000377 (NFE) ^{2} + 0.011 NFE% - 0.152. Metabolized energy (ME) was calculated by the equation of Garrett (1980): ME (Mcal kg^{-1}) = 0.82 DE. Net energy (NE) was calculated as following: NE (Mcal kg^{-1}) = 0.5 × ME (Le Houerou, 1980).

Statistical Analysis: The experimental design was a randomized complete block in a split plot arrangement. The mean separation among treatment means for locations and seasons was obtained by using the Least Significant Difference (LSD) test (Steel and Torrie, 1980). Effects were considered in all statistical calculations for p-values <0.05.

III – Results and discussion

The variation in nutritional quality of *Prosopis juliflora* between autumn and spring seasons in the three studied sites are presented in Tables 3 and 4. The results indicated that the nutritive values of *P. juliflora* plants were influenced by seasons and sites variation.

Dry matter (DM) content varied among the three locations and was highest in Makkah (22.43%). *P. juliflora* had higher DM content in autumn season than in spring season. The higher percentage of dry matter in Makkah and Jeddah compared to that in Taif should be attributed to the lower precipitations and the higher temperatures in these two sites.

In the present study, the crude protein of *P. juliflora* shrubs was significantly influenced (P<0.05) by seasonality. Lower CP was found in autumn harvest (12.10 %) than in spring one (14.56 %) (Table 3). This was mainly due to wetter conditions in spring compared with those in autumn (Table 1). On average, *P. juliflora* shrubs contained more protein (14.61%) at Taif site followed by Jeddah (13.12 %) and Makkah sites (12.26 %). The variation in the nutritive value of *P. juliflora* shrubs might also be attributed to the site potential in terms of edaphic factors and temperature conditions. The interaction season x site effect for CP was significant (Table 3). It has been shown that higher temperatures accelerate the conversion of photosyntates into structural compounds. Results obtained in current study are in agreement with those of Singh and Todaria (2012) who reported that nitrogen concentration in *Quercus serrata* foliage plants increased with the altitudinal gradient where maximum level of crude protein was found in spring season. Ball *et al*., (2001) also concluded that many forage species tend to have lower quality when grown in warm regions than in cool area. The present findings are also in agreement with those of Akin *et al*., (1987) and Sebetha *et al*., (2015).

Ash content was affected by both season and site; however, plants harvested in fall season had over 16% more ash than plants harvested in spring. Plants in Taif and Jeddah sites had roughly 20% less ash than those harvested from Makkah site. According to Kituku *et al*., (1993), ash content of for-

age crops changes with seasonal variations. Crude fiber (CF) was significantly affected by both season and site (P<0.05). As expected, lower CF content of *P. juliflora* shrubs was recorded during spring, (37.01%) compared to that recorded in autumn (40.89%). Moreover, CF content of *P. juliflora* plants grown was higher in Makkah (41.59%) than in Jeddah and Taif (39.53 and 35.73%, respectively) and this may be due to the hotter and dryer weather conditions of the two latest sites. Similarly, The highest CF (43.39%) and lowest one (33.72%) was obtained from plants grown in Makkah and Taif in autumn and spring, respectively. An opposite relationship between crude fiber and crude protein was also detected (Table 3). Similarly, El-Morsy (2009) reported that crude fiber content of domestic plants growing in Egyptian desert was lower in spring than in autumn.

Table 3. Effect of season, site and their interaction on dry matter (DM), crude protein (CP), ash, crude fiber (CF), ether extract (EE), nitrogen free extract (NFE), acid detergent fiber (ADF), neutral detergent fiber (NDF) and lignin of *P. juliflora.* Means are averaged over two growing seasons (autumn and spring) and five replications

Treatment/parameters		DM %	CP %	ASH %	CF%	EE%	NFE%	ADF%	NDF%	Lignin %
					Season					
Autumn		22.19	12.10	11.29	40.89	2.93	32.79	26.34	37.95	9.28
Spring		20.77	14.56	9.46	37.01	2.98	35.99	36.46	39.44	9.51
$L.S.D._{0.05}$		0.33	0.71	1.20	0.75	NS	0.84	1.45	1.14	0.18
					Site					
Makkah		22.46	12.26	9.43	41.59	2.71	34.01	34.45	35.72	9.54
Jeddah		21.73	13.12	9.85	39.53	2.85	34.65	31.32	39.10	9.74
Taif		20.25	14.61	11.86	35.73	3.29	34.51	28.43	41.27	8.90
$L.S.D._{(0.05)}$		0.89	0.87	1.86	0.69	0.16	NS	1.98	1.72	0.61
					Season × site					
Autumn	Makkah	23.45	11.12	9.17	43.38	2.65	33.68	29.15	39.11	9.36
	Jeddah	22.58	12.05	9.59	41.56	2.85	33.95	26.80	36.36	9.04
	Taif	20.53	12.99	9.64	37.73	3.28	36.36	23.08	38.39	9.44
Spring	Makkah	21.46	13.40	9.69	39.80	2.78	34.33	39.76	32.33	9.72
	Jeddah	20.88	14.05	10.12	37.50	2.85	35.48	35.84	41.84	10.45
	Taif	19.97	16.23	14.08	33.72	3.30	32.67	33.79	44.14	8.36
$L.S.D._{(0.05)}$	NS	1.14	2.80	0.94	0.23	1.72	NS	NS	1.21	

NS: not significant, $L.S.D._{0.05}$= least significant difference at 5% level.

There was no significant effect of season on ether extract (EE) content of *P. juliflora*. However, plants grown in Taif had similar EE content (13%) that those in the two other locations (Table 3). These results are in agreement with those of Nasrullah (2004) who reported a significant effect of altitude and altitude × season interaction on ether extract.

Nitrogen free extract (NFE) was higher in spring than in autumn. This may be due to the higher moisture availability in the soil, which increases nutrient uptake by plants in spring. No significant difference in NEF was detected between the three locations. Similar result was reported by Singh and Todaria (2012) on *Quercus serrata* foliage plants while different results was reported by Kim *et al*. (2006) on oat varieties forage where ADF and NDF values were significantly higher in spring than in autumn.

The lignin content is generally considered as an anti-quality component in forage plants since it affects the nutritional availability (digestibility) of plant fiber. Overall lignin content ranged from 8.36 to 9.72% with a mean of 9.4%. The highest lignin content was detected at Makkah site in spring season compared to that in Taif site (8.36%) in the same season (Table 3).

Acid detergent fiber (ADF) and Neutral detergent fiber (NDF) were significantly differents among growing seasons and the locations (Table 3). The ADF and NDF values were significantly higher (P<0.05) in spring than in autumn. This could be attributed to the flowering stage of *P. juliflora* shrubs which begins roughly in late February-March in the studied locations. Also more moisture availability in spring leads to the production of plant cells with thinner cell wall (Singh and Todaria, 2012).

Calcium (Ca), Phosphorus (P), Potassium (K) and Magnesium (Mg) contents in *P. juliflora* were higher in autumn season. Similarly, no significant effect of sites was observed on Ca, P, K and Mg contents in *P. juliflora* (Table 4). It is worth to note that soil of the studied locations is considered unfertile. According to Nasrullah *et al.*, (2004), the desert areas where they conducted their research works were poor in nutrients and mineral contents of forage plants were generally lower in rainy seasons where the leaching of minerals from the soil is higher.

Table 4. Effect of season, site and their interaction on Calcium (Ca %), Phosphorus (P %), Potassium (K %),Magnesium (Mg%), total digestible nutrients (TDN %), digestible energy (DE %), metabolized energy (ME %), net energy (NE MJkg^{-1}) and gross energy (GE Mcal kg^{-1}) of *P. juliflora* shrubs. Means are averaged over two growing seasons (autumn and spring) and five replications

Treatment/parameters		CA	P	K	Mg	TDN	DE	ME	NE	GE
						Season				
Autumn		4.21	0.20	2.67	0.69	55.87	2.27	1.86	0.93	425.05
Spring		3.01	0.17	2.13	0.52	54.14	2.44	2.00	1.00	433.91
L.S.D.$_{0.05}$		NS	NS	NS	NS	NS	NS	NS	NS	6.13
						Location				
Makkah		3.90	0.22	2.18	0.61	55.58	2.32	1.90	0.95	432.15
Jeddah		3.51	0.18	2.45	0.55	55.07	2.35	1.93	0.96	431.11
Taif		3.40	0.22	2.59	0.64	54.34	2.38	1.95	0.98	425.05
L.S.D.$_{(0.05)}$		NS	NS	NS	NS	NS	NS	NS	NS	NS
						Season × Location				
Autumn	Makkah	4.20	0.29	2.68	0.68	55.69	2.28	1.87	0.85	432.30
	Jeddah	4.21	0.15	2.58	0.67	55.17	2.31	1.90	0.95	431.89
	Taif	4.20	0.17	2.80	0.71	55.21	2.41	1.97	0.99	432.72
Spring	Makkah	3.60	0.15	2.22	0.53	54.35	2.36	1.93	0.97	432.05
	Jeddah	2.84	0.21	1.79	0.43	52.83	2.39	1.96	0.98	430.05
	Taif	2.59	0.17	2.39	0.59	53.18	2.36	1.93	0.97	417.36
L.S.D.$_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	

NS = Not Significant; L.S.D.$_{0.05}$= least significant difference at 5% level.

Total digestible nutrients percentage (TDN %) estimates the feed energy available to the animal after digestion; it was not significantly influenced by either location or season and remained unchanged (Table 5). It ranged between 53 % at Jeddah and 56% at Makkah in spring. Similarly, no significant differences between the treatments and/or their interaction were detected for digestible energy (DE), metabolized energy (ME), net energy (NE MJkg^{-1}), and gross energy (GE Mcal kg^{-1}) (Table 4).

IV – Conclusion

The availability of feed in desert areas due to scarcity of water is a biggest challenge to the agriculture. Local fodder trees and shrubs in these areas are considered as important source of feed. In this study, the performance of *Prosopis juliflora* in two harvest seasons in three locations was evaluated. It was concluded that *P. juliflora* can be considered as acceptable forage with relatively

high crude protein and low crude fiber at higher elevation and wetter conditions. Furthermore, in spring season, the forage quality is relatively superior.

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Developing annual cereal-legume mixtures in dairy goat farms in South-West of France, to improve protein self-sufficiency and reduce feeding costs

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Abstract. Greater use of annual cereal-legume mixtures in grains is one solution to improve goat farms sustainability and protein self-sufficiency. Still few references are available about its use in dairy goat systems, despite its interests (low-input culture, resistance to bio-aggressors, crude protein yield). For 3 years (2016 to 2018), 113annual cereal-legume mixtures have been studied, both in commercial farms (REDCap: 101 samples) and in experimental unit (Inra Patuchev: 12 samples). Every sample represents an annual cereal-legume mixture produced by a breeder on his farm (plots of 8.8 ha +/-5.3), and given to goats. For each sample, we collect information on the sown mix, sowing rate, soil type, weather and technical route. We measure the yield, the proportion of each species and the quality of the harvested mix. Production costs are also estimated. They are often composed of triticale, peas, oats, faba beans, vetch and/or barley. 48% of annual cereal-legume mixtures are made of 3 or 4 species, with about 300 seeds/m² sown (+/– 72). On average, 3.5 t /ha (+/– 0.9) are harvested. It produces an interesting feed for animals, with 88.2% (+/– 0.04) of digestibility of organic matter,1 UFL (+/-0.04) and 15.7% (+/-2.8) of crude proteins. Annual cereal-legume mixtures represent 10% of goat requirements and 17% of protein requirements. An analysis of the database shows that i/mixtures with about 10% of fabaceae, ii/presence of faba bean (10-15 grain/m²) and iii/about 3-4 species secure yield and feeding value. These references will help goat farmers to develop the use of annual cereal-legume mixtures in dairy goat systems.

Keywords. Goat – Annual cereal-legume mixture – Protein self-sufficiency – Grain.

Développement de mélanges céréales-protéagineux (méteils) dans les élevages de chèvres laitières du sud-ouest de la France, pour améliorer l'autonomie protéique et les coûts d'alimentation

Résumé. *une plus grande utilisation des mélanges céréales-protéagineux (méteils) récoltés en grain est une solution pour améliorer la durabilité et l'autonomie alimentaire des élevages de chèvres. A l'heure actuelle, peu de références existent sur son utilisation dans les systèmes d'élevage caprin, malgré ses nombreux intérêts (culture bas-intrant, résistance aux bio-agresseurs, rendement protéique). Pendant 3 ans, de 2016 à 2018, 113 méteils ont été étudiés, à la fois dans des élevages (REDCAP) et sur le dispositif expérimental Patuchev (Inra). Chaque échantillon correspond à un mélange produit par un éleveur dans sa ferme (les parcelles mesurent en moyenne 8,8 ha +/-5,3), et distribué aux chèvres. Pour chaque échantillon, nous avons récolté des informations sur la composition du mélange semé, la densité de semis, le type de sol, les conditions météorologiques et l'itinéraire technique. Nous avons mesuré le rendement, la proportion de chaque espèce récoltée, et la valeur alimentaire du mélange. Le coût de production a également été estimé. Ces mélanges sont souvent constitués de triticale, pois, avoine, féverole, orge et/ou vesce. 48% des méteils sont composés de 3 ou 4 espèces, semé à une densité de 300 graines/m² (+/-72). En moyenne, 35 qx sont récoltés par hectare. Un aliment intéressant pour les chèvres est produit, avec 88,2% de digestibilité, 1 UFL et 15,7 % de MAT (protéines). Cette récolte représente dans les élevages 10% des besoins massiques des animaux et 17% des besoins en protéines. Une analyse de la base de données montre que les mélanges avec 10 % de protéagineux semés, la présence de la féverole et des mélanges avec 3-4 espèces sécurisent le rendement et la valeur alimentaire. Ces références vont aider les éleveurs de chèvres laitieres de développer cette culture de méteil.*

Mots-clés. *Mélanges céréales-protéagineux – Méteil – Grain – Chèvres – Autonomie protéique.*

I – Introduction

Increasing feed self-sufficiency and grassland use leads to reduce feeding costs and negative environmental impacts of goat farms. In the south-west of France, a research and development scheme for high performance and sustainable goat farming has been created: REDCap and Patuchev (Caillat and Jost, 2015). It gives a wide place to i/ experiments in experimental units (Patuchev) and on farms (REDCap), ii/ exchanges between scientists, advisors and breeders to support the emergence of innovations and iii/ spread new knowledge on these topics. The network REDCap and the experimental plateform Patuchev of Inra work on these topics, using the Agroecology principles (Altieri, 2002): i) designing farming systems based on biological regulations and interactions between the components of the farm, ii) increasing local feed resources and inputs self-sufficiency, iii) working with local actors.

In western France goat farms, only 25% of concentrates are produced in farm and the level of protein self-sufficiency is 38%, which is quite low (Brocard *et al*., 2016). Greater use of home-made concentrate, as for example annual cereal-legume mixtures harvested in grains and given to goat as a concentrate, is one solution to improve goat farms sustainability and protein self-sufficiency.

Some farmers are using this opportunity. However, still few references are available about its use in dairy goat systems, despite its interests (low-input culture, resistance to bio-aggressors, crude protein yield).

II – Material and methods

During 3 years (2016 to 2018), 113 annual cereal-legume mixtures have been studied, both in commercial farms (REDCap: 101 samples) and in experimental unit (Inra Patuchev: 12 samples). Every sample represents an annual cereal-legume mixture produced by a breeder on his farm (plots of 8.8 ha +/-5.3), and given to goats in grain. The studied area concern two Region: Nouvelle-Aquitaine and Pays de la Loire. For each sample, we collect information on the sown mix, sowing rate, soil type, weather and technical route. Yield, proportion of each species and quality of the harvested mix are measured.

Finally, production costs (Perel method[1]) and impact on self-sufficiency are also estimated (Idele method: Contribution to goat requirements and protein requirements, Bossis *et al.*, 2015).For biochemical analyses, all samples are analyzed by the reference methods at LABCO of Surgères. Feeding values are calculated by tables Inra 2007.

III – Results and discussion

1. Description of annual cereal-legume mixtures used in dairy goat farms in Western France

Mixtures are on average composed of 4 species (+/-1.3). However, their composition is variabble: 30% of mixtures are composed of 2 species, 22% of 3 species, 25% of 4 species and 23% of more than 5 species. The more complex one count 9 species.

There is also diversity in terms of species used. 6 different cereals and 5 legumes are used by farmers. Table 1 presents the frequency of presence of each specie. Presence of triticale, pea, oat and faba beans can be noticed in more than half of mixtures. Other species are often used in complex

1. Perel method : http://www.perel.autonomie-fourragere-des-elevages.fr/couts-des-fourrages/

mixtures. Lupine is few used by farmers, because of the variability of its yield and the necessary to have a specific soil.

Table 1. Frequency of presence of each specie in mixtures

Triticale	Forage pea	Oat	Faba bean	Spelled	Vetch	Pea	Barley	Corn	Lupin	Rye
85%	75%	56%	50%	23%	21%	17%	22%	7%	6%	4%

Sown density is 297 seed/m² (+/-72), which is quite high (recommendation is 260 seeds of triticale/m² according to arvalis, 2019). Mixtures are composed of 10% of legumes seeds, in terms of seed sown. On average, 3.5 t (+/– 0.9) are harvested during summer.

54% of mixtures are produced with an organic agriculture label. Farmers often say “annual cereal-legume mixtures only need to be sown and harvested”. Indeed 92% of mixtures have no phytosanitary treatment, 88% no weeding and 85% no mineral nitrogen added.

2. Interest of annual cereal-legume mixtures for goat diet

These mixtures are an interesting feed for goats, with 88.2% (+/– 0.04) of digestibility, 1 UFL1 (+/-0.04) and 15.7% (+/– 2.8) of crude proteins. There are few variations on digestibility and energy values. Variations are more important on crude protein.

Table 2 present the diversity of yield and nutritive values, according to criteria: yield and crude protein value. 4 groups were made to show the diversity of success of this culture.

Table 2. Productivity of annual cereal-legume mixtures (source: REDCap)

	No. of samples	Yield (t/ha)	Crude Protein (as fed %)	Protein yield (kg of CP/ha)	Contribution to goat requirements	Contribution to goat protein requirements
Average	113	3.5	15.7%	595	10%	17%
High yield – High protein value	36	3.9	17.9%	698	13%	21%
High yield – Low protein value	24	2.2	18.6%	409	12%	19%
Low yield – High protein value	43	4.2	12.8%	538	14%	16%
Low yield – Low protein value	8	1.9	12.2%	231	8%	9%

[2]UFL = Unité Fourragère Lait; Net energy for lactation in MJ = UFL × 6.7 for grass (all types) and UFL × 6.8 for maize silage.

3. Interests of annual cereal-legume mixtures to improve protein self-sufficiency andreduce feeding costs

In terms of productivity, one hectare of mixture produce 595 kg of crude protein. There is a large variability (+/-213).

In the followed up farms, annual cereal-legume mixtures represent 10% of goat requirements and 17% of protein requirements. “Best mixtures” (high yield and protein value) produce 21% of protein requirements of goats.

Production costs were also estimated in 2016. This culture costs 385 €/ha (+/-60): 158 € of seeds, 125 € of mechanic works and inputs and 103 € of harvest. It represents 144 €/t or 8.5 €/% of CP.

IV – Conclusion

Cereal-legume mixtures are an opportunity for goat farmers, to improve their protein self-sufficiency, and in the mean-time to reduce input use and feeding costs. However, there is quite an important diversity of mixtures, and of successful. Next step will be to better understand the evolution of mixture, in terms of productivity and nutritional values. The goal is to propose recommendations to farmers. A fast analysis of the database shows that i/mixtures with about 10% of fabaceae, ii/presence of oats (10-15 grain/m²) and iii/about 3-4 species secure yield and feeding value. These references will help goat farmers to develop the use of annual cereal-legume mixtures in dairy goat systems.

With the development of goat organic farming, the promotion of protein self-sufficiency and the goal to decrease inputs in cultures, annual cereal-legume mixtures is an interesting culture for goat farmers in South-West France.

Acknowledgement

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Biomass production of different annual cereal-legume intercrops under Moroccan conditions

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Abstract. Annual cereal-legume forage mixtures are increasingly used in forage production in Morocco. Four forage cereals oat (cv Ghali), barley (cv Tamellalt), triticale (cv Juanillo) and rye (cv Petkus) were evaluated in mixture with three fodder legumes, fodder pea (*cv Naima*), *Vicia sativa* (cv Nawal) and *Vicia villosa* (cv Ghazza). Two years study was carried out at El Koudia location (N 34°03', O 6°46') to investigate the forage yield and growth rates of legumes-cereals mixtures at seeding ratio 75:25 for legume and cereal, respectively. Results showed significant differences among cereals-legumes intercrops for forage dry matter. The average yields were 8.7 and 6.6 t ha^{-1} respectively for first year and second year. Intercrops of oat-legumes and triticale-legumes provided higher and more stable yields for two years. Rye-legumes intercrops produced intermediate yields, while production of barley-legumes mixtures was lower for both seasons. Best yields were achieved for oat and triticale mixtures with pea in the first year and of both pea and *Vicia sativa* during the second year. According to the results, yields of cereals intercropped with *Vicia villosa*, were lower than yields of cereals intercropped with *Vicia sativa* or pea, except for barley during the first year. The proportions of pea and *Vicia sativa* in harvested yields were significantly higher than those of *Vicia villosa* for all the tested mixtures, indicating that pea and secondly *Vicia sativa* were more competitive when intercropped with any of the tested cereals.

Keywords. Forage – Cereals – Fodder legumes – Mixture – Oat – Barley – Rye – Triticale – Fodder pea – Vetch.

Production de biomasse de différents annuels cultures associées céréales-légumineuses sous conditions marocaines

Résumé. *La culture des mélanges de céréales et de légumineuses fourragères annuelles est une pratique traditionnelle de production fourragère extensive dans les pays méditerranéens. Elle est de plus en plus utilisée dans plusieurs zones au Maroc. Ainsi, quatre céréales fourragères avoine (cv Ghali), orge (cv Tamellalt), triticale (cv Juanillo) et seigle (cv Petkus) ont été évaluées en mélange avec trois légumineuses fourragères, pois fourrager (cv Naima),* Vicia sativa *(cv Nawal) et* Vicia villosa *(cv Ghazza) pendant deux années au site d'El Koudia (N 34°03', O 6°46') pour déterminer les rendements fourragers et établir les meilleures combinaisons au point de vue biomasse et qualité. Les mélanges légumineuses-céréales ont été semés à 75:25 pour les légumineuses et les céréales respectivement. Les résultats ont montré des différences significatives entre les cultures associées pour la matière sèche fourragère. Les rendements moyens ont été de 8,7 et 6,6 t ha^{-1} respectivement pour la première et la deuxième année. Les cultures intercalaires d'avoine-légumineuses et de triticale-légumineuses ont donné de bons rendements en outre stables pendant les deux années. Les rendements des mélanges seigle-légumineuses ont été intermédiaires, alors que la production des mélanges d'orge-légumineuses s'est révélée plus faible pour les deux saisons. Les meilleurs rendements ont été obtenus par chacune des cultures d'avoine et de triticale mélangées avec le pois et avec* Vicia sativa. *Les résultats ont également montré que les rendements de chaque céréale intercalée avec* Vicia villosa *étaient inférieurs aux rendements des autres mélanges. Les proportions de pois et de* Vicia sativa *dans le fourrage récolté ont été significativement plus élevées que celles de* Vicia villosa*, ce qui montre que le pois et la* Vicia sativa *soient plus compétitifs lorsqu'ils sont mélangés avec chacune des quatre céréales testées.*

Mots-clés. *Fourrage - Céréales – Légumineuses fourragères – Cultures intercalaires – Mélange – Avoine – Orge – Seigle – Triticale – Pois fourrager – Vesce.*

I – Introduction

Annual cereal-legume forage mixtures are considered as a traditional practice for extensive forage production in the Mediterranean countries. These mixtures are increasingly used in forage production areas in Morocco in order to enhance forage productivity and to promote the quality of harvested yields as reported by Gebrehiwot *et al*. (1996). Intercropping cereals with fodder legumes is expected to improve cropping systems, showing agronomic, nutritional and economic advantages compared to sole crops (Bedoussac, 2009). Intercropping is an effective system to promote yield stability and forage nutritive quality according to the crops genotypes and the environmental conditions (Ross *et al*., 2004, Lithourgidis *et al*., 2006).

Since the intercropping system is based on the complementarity between the species involved in the mixture, it is quite important to choose adequate partners to ensure the success of the system as whole. Hence, the aim of this study was to evaluate the productivity of forage intercrops based on annual fodder legumes (vetches and pea) and annual small grain cereals (barley, oat, rye and triticale) and to determine their best combinations under Moroccan rainfed conditions.

II – Material and methods

Four cereals species, oat (*Avena sativa* cv Ghali), barley (*Hordeum vulgare* cv Tamellalt), triticale (*Triticosecale* cv Juanillo) and rye (*Secale cereal* cv Petkus) were tested in mixture with three fodder legumes (*Vicia sativa* cv Nawal, *Vicia villosa* cv Ghazza and *Pisum arvens* cv Naima), at a seeding ratio of 75:25 for legume and cereal respectively. The trial was conducted for two years and was located in El Koudia experimental domain (N 34°03', O 6°46') in Morocco, on a sand loamy soil. For both years, sowing was made during the last decade of November in a density of 300 seeds m^{-2} based on seed weights. The experimental design was a randomized complete block with 12 treatments (combination of 4 cereals and 3 legumes) replicated three times. Plot size was 2.4 x 6 m. Measurements concerned forage yield, corresponding to 60% of fresh biomass, dry matter yields and species proportions at harvest. Mixtures were harvested around milk stage of cereals (approximately at pod setting of legumes). Statistical ANOVA analysis was performed using SAS software (SAS, 1990). Means comparisons between treatments were estimated according to Least Significant Differences (LSD) test with $\alpha = 0.05$.

III – Results and discussion

The weather conditions during the two growing seasons were quite different in the trial location. In the first year, annual rainfall reached 414 mm and had an irregular pattern with low rainfall at early growth cycle and a wet spring. During the second year, even with similar amount, rainfall pattern was different. The maximum rainfall was received just after sowing and a drought occurred at spring. Rainfall distribution was irregular with a maximum received in two months (December and January), followed by a completely dry period from February to mid-April. This rainfall pattern harmed seed emergence of barley and *Vicia villosa* species.

Seedling emergence occurred two weeks after sowing and averaged 78%. Plant covers were heterogeneous, especially in stands involving barley and *Vicia villosa*, which had weak and slow emergence, especially in the first year.

1. Forage production

Analysis of variance for forage production showed differences ($P > 0.05$) among the tested intercrops in both years. Harvested yields averaged 13 t/ha in both years and intercrops kept similar trends of biomass accumulation except those with triticale, which yielded significantly larger quantity of hay in the second year.

Oat intercropped with each of the three legumes (pea, *Vicia sativa* and *Vicia villosa*) revealed high yield potential at harvest, exceeding the other cereals-legumes mixtures. Furthermore, mixtures of rye and legumes reached higher levels of yield compared to those with barley. Yields from triticale-legumes intercrops were intermediate between the rye-legumes and barley-legumes mixtures (Fig. 1).

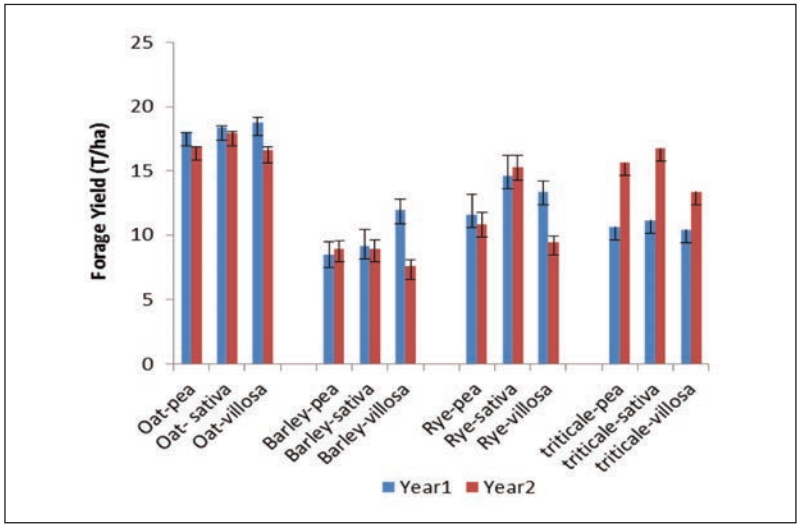

Fig. 1. Two years forage production of oat, barley, rye and triticale intercropped each with *Vicia sativa, Vicia villosa* and pea at El Koudia location.

2. Dry matter yields

Significant differences (P<0.001) were recorded among the tested cereals-legumes intercrops for forage dry matter. The year effect was significant for this parameter (F_{pr}=0.0021) and the average yield was significantly higher in the first year (8.7 t ha^{-1}) compared to second year (6.6 t ha^{-1}). The higher yields were achieved by oat and triticale intercropped with pea.

However, intercrops with barley and the three legumes produced lower yields, likely due to an inappropriate variety choice. Besides, intercrops of oat, barley and triticale with pea had higher yields than when intercropped with *Vicia sativa* or *Vicia villosa*. In the second year the trend was confirmed with a net catch-up of the mixtures of the three cereals (oat, triticale and barley) intercropped with *Vicia sativa*.

However, forage yields of cereals mixed with *Vicia villosa*, were lower than those of cereals intercropped with *Vicia sativa* or *Pisum arvens*, except for barley during the first year (Fig. 2).

3. Proportions of fodder legumes at harvest

The proportions of legumes in the harvested forage of intercrops were more or less similar for both years. Fodder legumes accounted for a large share of harvested forage and their contribution in yield was significantly higher in the case of fodder pea-cereals and *Vicia sativa*-cereals (Fig. 3). The proportions went up to the 75:25 initial proportion in the case of barley-pea and triticale-pea mixtures. However, intercropping *Vicia villosa* with cereals resulted in low amounts of this legume within intercrops. Indeed, proportions of *Vicia villosa* in harvested forage ranged between 6 and 20% significantly below of sown proportions.

It seems that the pea and secondly *Vicia sativa* were more competitive than *Vicia villosa* when intercropped with any of the four tested cereals.

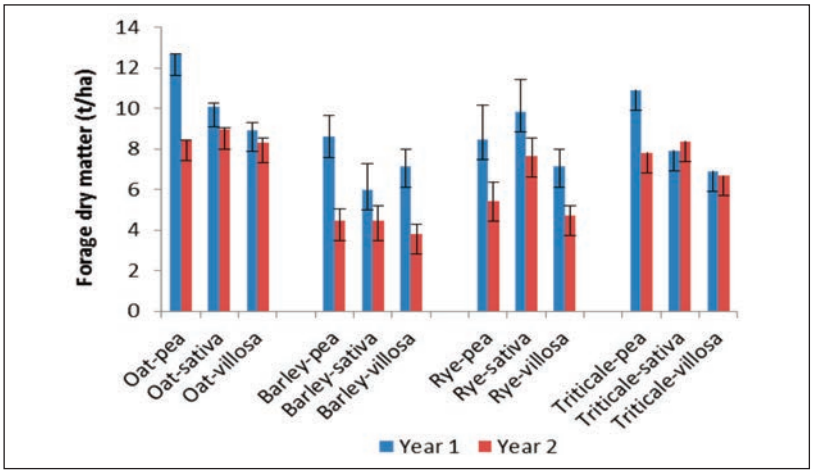

Fig. 2. Forage dry matter of 12 intercrops generated from oat, barley, rye and triticale mixed with *Vicia sativa, Vicia villosa* and pea at El Koudia location.

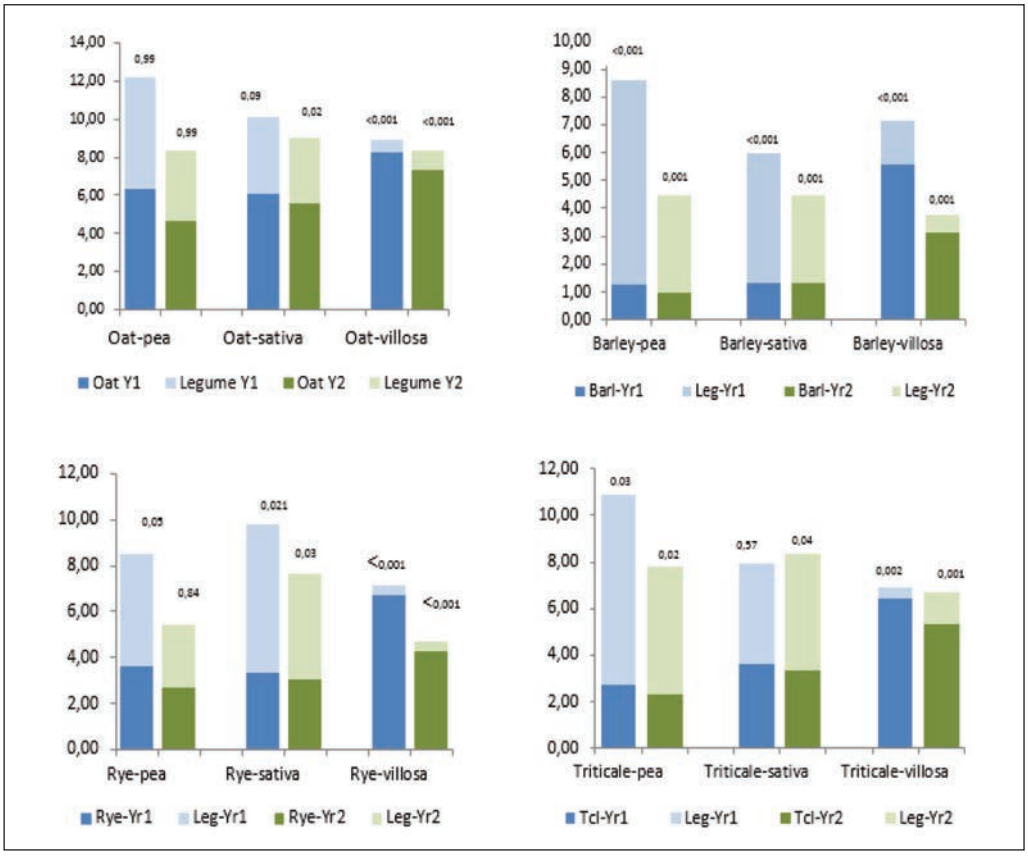

Fig. 3. Shares of cereal and fodder legumes in the forage biomass produced by 12 intercrops generated from oat, barley, rye and triticale mixed with *Vicia sativa, Vicia villosa* and *Pisum arvens* at El Koudia location. (*The probability of differences significance are indicated on the top of each column*).

IV – Conclusion

The present study demonstrates that intercropping of vetches and pea with small grain cereals (oat, barley, rye and triticale) affects forage yields. Intercrops from oat-legumes and triticale-legumes provided high and stable yields. Rye-legumes intercrops showed intermediate yields and production from barley-legumes mixtures was lower in both seasons. Higher yields were achieved by oat and triticale intercropped with pea and *Vicia sativa*. However, yields of each cereal intercropped with *Vicia villosa*, were lower than those intercropped with *Vicia sativa* or pea. Furthermore, shares of pea and *Vicia sativa* to cereals in harvested yields were higher than those of *Vicia villosa* for all intercrops, showing that pea and secondly *Vicia sativa* were more competitive when intercropped with any of the four tested cereals.

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Influence of different *Rhizobium sullae* strains and soil fertility on the agronomic performance of Sulla (*Sulla coronaria* L.)

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Abstract. Sulla is widely used as a forage legume in several Mediterranean regions, however only a limited area of Sardinia is cultivated to Sulla. Its cultivation is manly confined to areas where its native specific rhizobium is available and soil pH is alkaline. Four farms were selected in the southern part of Sardinia with slightly acid soils and where the Sulla had never been sown. Intensive and large-scale trials were conducted to assess the adaptation of Sulla to different soil types and to assess the effectiveness of a range of elite Sulla rhizobial strains. The un-inoculated control treatments had significantly lower nodule numbers at all sites, indicating the presence of a very low Sulla rhizobial background and stressing the importance to inoculate Sulla in the region. Some of the paddocks had a challenging fertility for the growth of Sulla; however the use of an effective and robust rhizobial strain such us WSM1592 and 79N2 was of paramount importance to successful growth the species.

Keywords. Forage species – Legume – Dairy sheep – Mediterranean environment.

***Influence de différentes souches de* Rhizobium sullae *et de la fertilité du sol sur les performances agronomiques de Sulla* (Sulla coronaria *L.*)**

Résumé. *Sulla est largement utilisé comme légumineuse fourragère dans plusieurs régions méditerranéennes, mais seule une zone limitée de la Sardaigne est cultivée en Sulla. Sa culture est confinée à des zones où son rhizobium natif spécifique est disponible et où le pH du sol est alcalin. Quatre fermes ont été sélectionnées dans le sud de la Sardaigne avec des sols légèrement acides et où Sulla n'avait jamais été semé. Des essais intensifs et à grande échelle ont été menés pour évaluer l'adaptation de Sulla à différents types de sol et pour évaluer l'efficacité de toute une gamme de souches rhizobiennes d'élite. Les traitements témoins non inoculés présentaient un nombre de nodules significativement plus faible sur tous les sites, ce qui indique la présence d'un très faible précédent milieu rhizobien de Sulla et souligne l'importance d'inoculer Sulla dans la région. Certaines des prairies présentaient une fertilité difficile pour la croissance de Sulla; cependant, l'utilisation d'une souche rhizobienne efficace et robuste, telle que WSM1592 et 79N2, était d'une importance primordiale pour la réussite de la croissance de l'espèce.*

Mots-clés. *Espèces fourragères – Légumineuses – Brebis laitières – Environnement méditerranéen.*

I – Introduction

Sulla (*Sulla coronaria* L.) is a short-lived perennial, deep-rooted pasture legume that is grown throughout Mediterranean countries where it is fed green, used for hay or as silage (Foote, 1988). The microsymbionts of Sulla display a high level of specificity for nodulation and nitrogen fixation (Yates *et al*., 2015). When effectively nodulated, Sulla plants can fix large amounts of nitrogen and produce adequate green biomass (Sulas *et al*., 2009). It is commonly found in clay calcareous soils

with alkaline pH and sometimes in slightly acidic soils. Sulla is widely used as a forage legume in several Mediterranean regions, however only a limited area of Sardinia is cultivated with Sulla. Its cultivation is manly confined to areas where its native specific rhizobium is available and soil pH is alkaline. However, the results from recent research showed that seed inoculation can successfully extend Sulla cultivation in soils not traditionally recommended (Sitzia *et al.,* 2018). The unsuccessful cultivation of Sulla on these latter soils was likely due to the use of poor inoculation methods and/or the presence of competitive and persistent, yet ineffective, rhizobial populations. Root-nodule bacteria isolated from nodules are commonly evaluated for traits such as plant infection, optimum N fixation, acid tolerance, persistence, broad spectrum compatibility within host species and competitiveness with an established background population of rhizobia (Howieson *et al.,* 1999). The focus of selection for one or more of these traits is related to the systems and environments where the strains are likely to be used. The standard process involves screening experiments in controlled environments and under field conditions. The aim of this research was therefore to investigate the effectiveness of several rhizobia isolated from Sulla, i.e. different *Rhizobium sullae* strains, under different edaphic conditions and to study the suitability of Sulla to Sardinian soils where traditionally it is not grown by farmers.

II – Materials and methods

Four dairy sheep farms, located in the Southern part of Sardinia, were selected to grow Sulla (note that Sulla was never cultivated in these farms before). Before sowing Sulla, soil pH, organic matter content total N (Kjeldahl method), available P (Olsen method) and exchangeable K were determined as described in Margesin and Schinner (2005). Soil texture was also investigated. For soil physico-chemical analyses, 10 soil samples (0-20 cm depth, approx. 1 kg each) were randomly collected from each plot, pooled together and sieved to <2mm in the laboratory to obtain a bulk sample. Triplicate soil samples from this latter were then used for each physico-chemical determination. Two experiments were carried out at each farm.

Sulla was inoculated in both experiments few hours before sowing with selected *R. sullae* strains using peat inoculants. Two rhizobial strains, i.e. 79N2 and 852N3, and the Australian commercial strain WSM1592 (Yates *et al*., 2015) were separately used for seed inoculation. Peat slurries were prepared by mixing the peat (containing the selected rhizobia) with the seed coating adhesive (250 g of peat inoculant, 1000 ml adhesive) and used to inoculate 30 kg of Sulla seeds. These were mixed with the slurry and then pelleted with fine lime. Uninoculated seeds were also included in both experiments.

Experiment I: the infectiveness of the three *R. sullae* strains was addressed during spring 2018 by assessing the nodulation numbers on plants grown in each farm. The nodulation assessment was carried out by assessing individual Sulla plants sampled from 1.5 m long rows organized in a randomized block design that included 3 rhizobial strains and an uninoculated control. Five months after seeding, a total of 40 plants (10 x replicate) per treatment were removed, and roots carefully washed. The total number of nodules was then recorded.

Experiment II: each farm paddock, was divided into 4 plots of 2500 m^2 each. Plots were sown in autumn 2017 with 30 kg ha^{-1} of commercial seeds (cv. Bellante). Plant establishment (i.e. plant number) was recorded approximately 45 days after seeding in 30 quadrats (900 cm^2 each) randomly positioned in each plot. In spring 2018, biomass production was measured by cutting 4 quadrats (0.5 m^2 each) per plot. Botanical composition was recorded separating Sulla from the weed species, then the Sulla component was dried at 60 °C and weighted. The plots during the year were grazed by dairy Sarda ewes when the sward reached 10 cm height.

Data were analyzed by GLM model. Differences between treatments were assessed by Tukey T tests ($P < 0.05$, SAS Institute, 2002).

III – Results and discussion

Three of the four sites (A, F and P) were slightly acidic with pH ranging from 5.9 to 6.8. Total amount of N for the four sites was over 1 mg/kg of soil, with the exception of site F that recorded 0.45 mg/kg of soil. The P content was suitable at sites C and P, although at sites A and F it was far below the critical levels for pastures. The organic matter content was similar for the four sites and ranged from 1.87 and 2.61% (Table 1).

Table 1. Soil characteristics at 0-10 cm depth for the 4 experimental sites

Site	GPS coordinate	Soil type[2]	pH	N g/kg	P mg/kg	K mg/kg	Organic g/kg	Matter C/N
A (Santadi)	39°03'N/8°43 'E	CL	5.9	1.37	1.97	96	2.61	19.63
C (Iglesias)	39°16'N/8°34'E	SCL	7.5	1.18	9.48	117	2.28	19.19
F (Flumentepido)	39°10'N/8°27'E	SCL	6.3	0.45	3.23	146	1.87	41.74
P (Iglesias)	39°18'N/8°34'E	SCL	6.8	1.20	13.02	132	2.38	19.99
w α=0.051			0.2	0.11	2.81	4.75	0.20	2.06

[1]Tukey's Significant Difference. [2]CL: clay loam; SCL: sandy clay loam.

During the trial, total annual rainfall was similar to the climatological value, but an erratic distribution was detected in all sites. In particular, a dry autumn was followed by an unusually wet spring (rainfall climatological value of May were 38.4, 41.6 and 42.8 in A, C and P, and F site, respectively; Table 2).

Table 2. Monthly rainfall (mm) during the experimental period (data from ARPAS Sardegna) in 2017

Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
A	18.6	21.2	59.6	58.8	24.8	54.8	127.6	30.8	199.4	55.8	0	651.4
C	22.6	3.6	72	160.4	28.6	119	206.6	47.2	158.2	54.4	0	872.6
F	20.4	10	64	81.4	24.4	81.8	153	38.6	169	22.4	0	665
P	22.6	3.6	72	160.4	28.6	119	206.6	47.2	158.2	54.4	0	872.6

The experiment I clearly highlighted the importance of *R. sullae* on plant nodulation and growth (not shown). The uninoculated control had significantly lower nodule numbers at all sites, particularly when compared to strain WSM1592 (Table 3). The lowest nodule numbers were recorded at site A which had the lowest pH and P content.

Table 3. Total nodule numbers on Sulla plants inoculated with different *R. sullae* strains and on Sulla uninoculated plants at four Sardinian sites (A, C, F and P)

Site	WSM1592	79N2	852N3	Uninoculated
A	2.28^{A}	0.28^{B}	0.28^{B}	0.28^{B}
C	6.34^{A}	4.13^{B}	3.90^{B}	1.07^{C}
F	3.07^{A}	2.40^{AB}	1.50^{B}	0.03^{C}
P	4.30^{A}	1.58^{B}	0.47^{B}	0.32^{B}

P<0.05 between treatments.

Similar results were observed at the plot scale (experiment II). Plant establishment ranged between 117(±10.24)/m^2 at F site to 221(±15.89)/m^2 at site A. The dry matter yield of the uninoculated treatments was always lower, and sometime negligible such as at P and F sites, compared to inoculated ones (Fig. 1). Overall, WSM1592 and 79N2 were the most effective strains allowing Sulla to produce adequate amount of biomass across three sites (A, C and P). The dry matter production at site F was the poorest and this was probably due to a poor strain adaptation to soil conditions (low P and pH).

It is important to note that the lowest nodulation score recorded for the three strains at site A (Table 3), had no effect on the dry matter production as much as for site F. Early nodulation sampling and slow formation of the nodules in low fertility soil may be the reason for this discrepancy. However, the sole nodulation score can be misleading when assessing the symbiotic performance of a rhizobial strain in the field. A parallel assessment of plant yield should be always recommended to investigate the suitability of plant-rhizobial combinations in different pedo-climatic conditions.

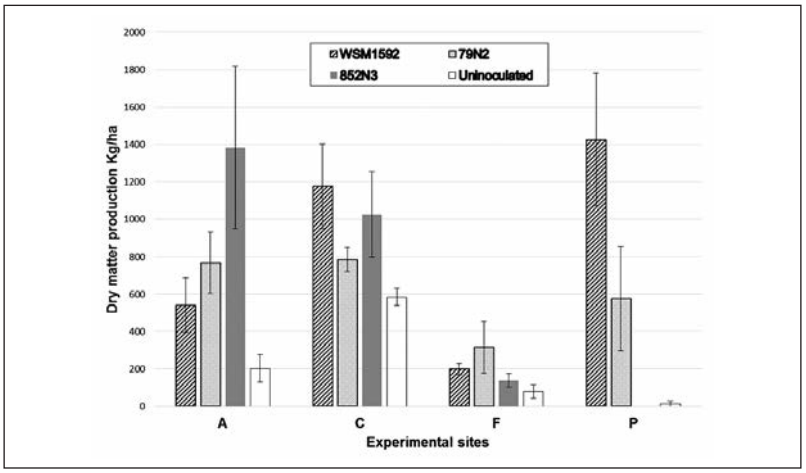

Fig. 1. Pasture dry matter production of Sulla inoculated with different *R. sullae* strains and of Sulla uninoculated at four Sardinian sites (A,C,F and P).

IV – Conclusions

The presence of *R. sullae* is fundamental for Sulla establishment where it was never cultivated before. The use of effective rhizobial strains such as WSM1592 or 79N2 can allow the successful growth of Sulla in these latter soils, unless the minimum requirements of soil fertility are respected.

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Comparative evaluation of winter forage legumes under Mediterranean rain-fed conditions

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Abstract. Forage production of adequate quantity of the proper quality is a timeless goal for ruminant production farming systems. Climatic conditions in semi-arid Mediterranean areas set a limit to this goal. With the aim to evaluate a range of forage legumes a trial was set up at the Agricultural University of Athens, where seeds were sown in a randomized design with two replicates. Forage species sown were: *Trifolium spumosum* (cv Bartolo), *Trifolium hirtum* (cv Hykon), *Trifolium dasyurum* (cv Sothis), *Trifolium glanduliferum* (cv Prima), *Trifolium michelianum* (cv Paradana), *Trifolium subterraneum* (Dalkeith), *Biserulla pelecinus* (Cashbah), *Ornithopus sativus* (Margurita), *Ornithopus compressus* (Santorini) *Medicago polymorpha* (Cavalier, Scimitar), *Medicago littoralis* (Angel). Quantity and quality characteristics (ash, crude protein, crude fiber as well as NDF and ADF contents) of the forage produced were recorded. It was observed that *M. polymorpha* (Scimitar) and *Trifolium dasyurum* (cv Sothis) were the most competitive against weeds and productive in forage DM, while nutritional characteristics were similar between species. It was concluded that productivity and competitiveness of a forage species (or cultivar) is a crucial factor for the production of rain-fed forage material of adequate quality under Mediterranean conditions.

Keywords. Forage legumes – Rain-fed crops – Harsh conditions – Nutritional quality.

Évaluation comparative des légumineuses fourragères d'hiver dans des conditions pluviales méditerranéennes

Résumé. *La production de fourrage en quantité suffisante et de qualité appropriée est un objectif intemporel pour les systèmes de production de ruminants. Les conditions climatiques dans les zones Méditerranéennes semi-arides limitent cet objectif. Dans le but d'évaluer une gamme de légumineuses fourragères, un essai a été mis en place à l'Université d' Agriculture d'Athènes, où des graines ont été semées de manière aléatoire, avec deux répétitions. Les espèces fourragères semées étaient:* Trifolium spumosum *(cv Bartolo),* Trifolium hirtum *(cv Hykon),* Trifolium dasyurum *(cv Sothis),* Trifolium glanduliferum *(cv Prima),* Trifolium michelianum *(cv Paradana),* Trifolium subterraneum *(Dalkeith),* Biserulla pelecinus *(Casbah),* Ornithopus sativus *(Margurita),* Ornithopus compressus *(Santorini),* Medicago polymorpha *(Cavalier, Scimitar),* Medicago littoralis *(Angel). Les caractéristiques quantitatives et qualitatives (cendres, protéines brutes, fibres brutes ainsi que les teneurs en NDF et en ADF) du fourrage produit ont été recueillies. Il a été observé que* M. polymorpha *(Scimitar) et* T. dasyurum (cv Sothis) *étaient les plus compétitives contre les mauvaises herbes et productives en matière de MS fourragère, alors que les caractéristiques nutritionnelles étaient similaires entre les espèces. Il a été conclu que la productivité et la compétitivité d'une espèce fourragère (ou d'un cultivar) est un facteur crucial pour la production de matériel fourrager pluvial de qualité adéquate dans des conditions Méditerranéennes.*

Mots-clés. *Légumineuses fourragères – Cultures pluviales – Conditions difficiles – Qualité nutritionnelle.*

I – Introduction

Livestock in Mediterranean areas, mainly sheep and goats, constitutes a major source of income for the rural population and contributes greatly to farmers' family subsistence through their products (meat, milk, skins wool etc.). They provide a range of ecosystem services such as support of biodiversity, protection of water and soil resources, recreational values, carbon sequestration, to list a few (Varela and Robles-Cruz, 2016). Although an important source of feed for these animals

is the grazed material of extensive rangelands, cereal straw and stubble, as well as grains cropped locally do so too (Porqueddu *et al*., 2017). However, there is often a shortage of good quality forage feed and in particular of protein content. Sown swards can effectively supply a substantial part of the productive ruminant's nutritional requirements. Moreover, the growing market for organic products is guiding animal farmers to increase the availability of grazed material (Doyle and Topp, 2003). This is more important in Mediterranean areas where pedoclimatic conditions are often marginal (Hadjigeorgiou, 2011).

Such shortages can be mitigated by cropping legume species adapted to drought and poor soils and integrating them into the mixed crop-livestock or agro-pastoral farming systems, as multi-purpose crops, to improve seasonal supply of quality feed and soil productivity (Baxevanos *et al*., 2017). Concrete knowledge of the cultivation and utilization of leguminous forages (either through grazing or as preserved feed) has increased greatly over the last few decades in temperate regions. Progress in plant selection and improvement has led to new species and advanced varieties of leguminous forages as well as the economic dimension of the cultivation of forage legumes has also been more fully understood (Rochon *et al*., 2004). Mediterranean climatic conditions and the poor soils are known to hamper productivity of conventional temperate species crops (Porqueddu *et al*., 2017). The information gap on growing efficiently forage legumes in Mediterranean is still large and the scientific basis for information is relatively inadequate to give practical advice on the whole range of farming cases (Gintzburge & Le Houerou, 2002; Ates *et al*., 2012) therefore new knowledge has to be added. A comparative study was undertaken to test, under marginal pedoclimatic conditions, forage legume germplasm of Mediterranean origin, which was mostly selected and produced in Australia.

II – Materials and methods

1. Growing the legume forages

At the Agricultural University of Athens (N 37º59'10'', E 23º42'29'', altitude 24 m a.s.l.), a comparative test was carried out, through a randomized two repetition design, which included 12 legume forage species and varieties thereof. The species tested (cultivar in parenthesis) were: *Trifolium spumosum* (Bartolo), *Trifolium glanduliferum* (Prima), *Trifolium michelianum* (Paradana), *Trifolium hirtum* (Hykon), *Trifolium subterraneum* (Dalkeith), *Trifolium dasyurum* (Sothis), *Biserulla pelecinus* (Cashbah), *Ornithopus sativus* (Margurita), *Ornithopus compressus* (Santorini) *Medicago polymorpha* (Cavalier, Scimitar), *Medicago littoralis* (Angel). Plots of 2.25 m^2 area (1.5 x 1.5 m), separated by corridors of 0.5 m were sown on 30/11/2017, with a density of about 200 seeds m^{-2}, after fine surface soil preparation and a light P_2O_5 fertilization. No herbicides or irrigation was applied on this trial.

2. Analytical methods

Forage material was harvested during mid-May 2018 from an area of 0.25 m^2 at the centre of each plot and dried at 60 ºC for 48 hours. Forage quality was assessed on the dried material after it was pre-ground with a hammer mill to pass a 6 mm sieve and then finely ground on a laboratory mill using a 1 mm screen. Analyses were conducted for moisture (AOAC method 930.15), crude protein concentration (CP) by the Kjeldahl method (AOAC method 984.13), ash content (Ash) by ashing overnight at 550º C (AOAC method 942.05), crude fiber (CF), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) on an ANKOM 220 (AOAC 978.10, AOAC 2002:04 and AOAC 973.18, respectively).

3. Statistical analysis

All data were subjected to a one-way Analysis of Variance (ANOVA) and Least Significant Difference (LSD) at 0.05 level was applied to define significantly different means among the species. Statgraphics Centurion 16 statistical package was used for this task.

III – Results and discussion

The soil on the site was characterised of a light type (SL), with low organic matter (OM) and Total N, alkaline (pH: 7.84) with high Ca. In fact Soil characteristics of the area were analysed as follows: pH 7.84, organic matter (OM) 1.48%, total nitrogen 0.243 %, $CaCO_3$ 26.2 %, phosphorus (P) 15.69 ppm, potassium (K) 180 ppm. Climatic conditions were characterised by low rain (230 mm during growth period) and mild air temperatures (no frost, an average of 10ºC at start and 25ºC at the end of trial, while average temperature during the whole period was maintained at 15.3ºC.

Table 1. Legume forage DM production and the crude chemical composition (Ash, crude protein, crude fiber and the fiber fractions (NDF, ADF), for the species tested (g/ 100 g of DM)

Species and varieties trialed	Herbage (g DM/m^2)	Ash (% DM)	CF (% DM)	NDF (% DM)	ADF (% DM)	CP (% DM)
Biserulla pelecinus (Cashbah)	411.2^{cd}	9.75^{ab}	27.55^{ab}	45.85^{bc}	29.98^{a}	11.85^{ab}
Medicago littoralis (Angel)	307.2^{abc}	9.89^{ab}	36.60^{f}	61.42^{g}	36.42^{de}	11.19^{ab}
Medicago polymorpha (Cavalier)	377.8^{c}	7.86^{a}	30.18^{cd}	51.21^{de}	33.62^{c}	10.63^{ab}
Medicago polymorpha (Scimitar)	722.0^{e}	7.60^{a}	28.08^{bc}	49.56^{cd}	31.81^{b}	11.52^{ab}
Ornithopus compressus (Santorini)	197.5^{ab}	14.46^{c}	26.72^{ab}	50.87^{d}	29.75^{a}	13.15^{bc}
Ornithopus sativus (Margurita)	182.7^{ab}	11.07^{abc}	28.64^{bc}	41.65^{a}	37.52^{ef}	8.67^{a}
Trifolium dasyurum (Sothis)	527.7^{d}	7.74^{a}	33.29^{e}	55.68^{f}	35.92^{d}	13.88^{bc}
Trifolium hirtum (Hykon)	185.2^{ab}	8.38^{ab}	32.18^{de}	55.29^{ef}	34.19^{c}	12.85^{bc}
Trifolium glanduliferum (Prima)	324.5^{bc}	8.82^{ab}	32.22^{de}	55.60^{f}	37.87^{f}	10.56^{ab}
Trifolium michelianum (Paradana)	415.3^{cd}	9.77^{ab}	27.67^{ab}	51.57^{def}	29.09^{a}	12.33^{b}
Trifolium subterraneum (Dalkeith)	174.6^{a}	12.10^{bc}	25.52^{a}	44.03^{ab}	29.11^{a}	11.96^{ab}
Trifolium spumosum (Bartolo)	395.9^{cd}	9.81^{ab}	28.81^{bc}	51.81^{def}	32.08^{b}	16.27^{d}
s.e.	13.6	0.365	0.232	0.389	0.131	0.337
P	0.0001	0.0634	0.0000	0.0000	0.0000	0.0542

The earliest flowering species were *Medicago littoralis* (Angel) and *Medicago polymorpha* (Scimitar and Cavalier) which started at 105 days. The herbage DM produced, on day 160, by each of the 12 legume forages varied widely between species. *Medicago polymorpha* (Scimitar) was the most productive, followed by *Trifolium dasyurum* (Sothis) (Table 1). At the same time *Trifolium subterraneum* (Dalkeith), *Trifolium hirtum* (Hykon) and *Ornithopus sativus* (Margurita) produced the least, thus demonstrating the vulnerability of the system.

Herbage nutritional characteristics varied also widely between species. CP content was higher for *Trifolium spumosum* (Bartolo), followed by *Trifolium dasyurum* (Sothis) and *Ornithopus compressus* (Santorini). An opposite pattern was observed for CF, NDF and ADF contents. The different legume forages matured at different times, while at sampling time not all species crops were at full maturation, therefore such differences are naturally expected.

IV – Conclusions

All legume forages tested produced hay of good quality for feeding of small ruminants, although at a range of productivity. However, some of them did mature quite early, which resulted in becoming able to complete their life cycle before drought period. It is advisable to try to persuade farmers testing new species in an effort to shift their crops to those that are more productive and to confront the adverse effects of the climate change phenomenon through fast growing species tolerant of warm weather.

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Chemical composition and *in vitro* digestibility of leaves of Tunisian *Ajuga iva*

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Abstract. This study aimed to determine chemical composition of leaves of *Ajuga iva* (L.) collected in winter from different Tunisian localities namely Dogga, Mograne and Nabeul. Leaves collected from Nabeul locality had high mineral contents (24.3%). High crude protein (CP) contents were recorded in leaves collected from Mograne locality (14.7%), whilethose collected from Dogga contained the lower levels (8.9%). Cell wall contents (NDF and ADF) varied from 29.3 to 37.0% (NDF) and from 22.2 to 30.1% (ADF). Lignification of cell wall varied between 13.5% (Nabeul) and 19.0% (Mograne). Irrespectively of their locality, methanol extracts of *A. iva* leaves were characterized by their high phenolic (13.6-14.0 mg gallic acid equivalent/g DM), and flavonoids (8.6-12.6 mg quercetine equivalent / g DM) contents. True in vitro dry matter digestibility (TID) varied between leaves collected from different localities but it was low (<80% DM). Results of this present study suggest that *A. iva* species, due to its high CP contents, would be appreciated by small ruminant grazing on natural pasture and cover part of their nutritional requirements.

Keywords: *Ajuga iva* – Chemical composition – Total phenols – Digestibility.

Composition chimique et digestibilité in vitro des feuilles de* Ajuga iva *collectées de la Tunisie

***Résumé**. Cette etude a pour objectif la determination de la composition chimique des feuilles de* Ajuga iva *(L.) collectées en hiver de différentes localités de la Tunisie : Dogga, Mograne Nabeul. Les feuilles collectées à Nabeul sont les plus riches en minéraux (24,3 %). La teneur en protéine brute (PB) la plus élevée se trouve au niveau des feuilles collectées à Mograne (14,7%).Cependant les feuilles collectées de Dogga contiennent les teneurs les plus faibles (8,9%). Les teneurs en paroi cellulaires (FND et ADF) varient entre 29,3 et 37,0% (FND) et entre 22.2 et 30.1 % (FAD). La lignification de la paroi cellulaire varie entre 13,5 (Nabeul) et 19,0% (Mograne). Indépendamment de leur provenance, les extraits methanoliques des feuilles d´*A. iva *sont caractérisés par leurs teneurs élevés en phenols totaux (13,6-14,0 mg gallic acid/g DM), et flavonoids (8,6-12,6 mg equivalent quercetine/ g DM). La digestibilité réelle in vitro (TIV) des feuilles d'*A. iva *est faible (<80% MS). Les résultats de cette présente étude suggèrent que les feuilles d'*A. iva*, vu leurs teneurs élevées en PB, devraient être bien appreciées par les petits ruminants sur des parcours naturels et pourraient couvrir une partie de leurs besoins azotés.*

Mots-clés. A. iva *– Composition chimique – Phenol totaux – Digestibilité.*

I – Introduction

Ajuga iva belongs to the Lamiaceae family, it is an herbaceous perennial plant (20-30 cm height) often woody in the base. It is widely distributed along the Mediterranean coast, mountainous regions and arid-semiarid areas. Stony places, waste ground and waysides are favourable habitats for *A. iva*. In Tunisia it is known under the common name of 'chendgoura'. Chemical studies on *A. iva* have revealed the presence of several flavonoids, tannins, terpenes, and steroids (Toiu *et al*., 2019). Other reported studies revealed its importance in traditional human medicine of different countries in the world (Makni *et al*., 2013). However, although it is well appreciated by small ruminants when they walk through transhumance routes to grazing lands, specially during flower-

ing season (April to October), there are no studies reporting the nutritional value of *A. iva* as a pastoral plant. Therefore our main objective in the present study is to highlight the pastoral aspect of *A. iva* throughout a phytochemical analysis and *in vitro* dry matter digestibility of its leaves.

II – Material and methods

1. Sampling and chemical analysis

Leaf samples of *A. iva* were collected from different Tunisian ocalities namely Dogga, Mograne and Nabeul in Winter 2015. In the laboratory they were oven dried (60°C, 48 h) and milled for passing through a 1-mm screen and kept in airtight plastic bottles for subsequent chemical analysis and in vitro dry matter digestibility (degradability and true digestibility). Dry matter, crude ash, crude protein and ether extract contents of tree leaves were determined according to the AOAC (1999). Cell wall (NDF and ADF) and acid detergent lignin (ADL) contents of leaves were determined according to the methods described by Van Soest *et al*. (1991).

2. Preparation of plant extracts and determination of total phenolic and flavonoid contents

In order to study the effect of the solvent on the total phenolic and flavonoid contents of *A. iva* leaves, extraction with two different solvents were used; water and methanol. Plant material (1 g) was weighed into dark colored flask and dissolved with 20 mL of either water or methanol and stored at room temperature. After 24 h, extracts were filtered and the supernatant was collected and concentrated using a rotary evaporator (60°C). The obtained dry extracts, i.e aqueous extract (AE) and methanolic extract (ME), were kept in sterile sample tubes and stored in a refrigerator at 4°C. The total phenolic content was determined using the method proposed by Wolfe *et al*. (2003). Briefly 50 µL of either ME or AE extract (diluted 20 times in water) were mixed with 50 µL of water and 400 µL of 10% Folin–Ciocalteu. Gallic acid (Sigma Aldrich) was used as a standard and the concentration of TP was expressed in mg standard equivalent per g DM. Total flavonoids (TF) content was determined using colorimetric method proposed by Yi *et al* (2008) mixing 1 mL of AE or ME with 1 mL methanolic solution (2% aluminum chloride, Sigma Aldrich) and incubating for 15 min at 25 °C. Absorbance was measured against a blank at 430 nm using quercetin as the standard. Results were expressed in mg standard equivalent/g DM. For PC and FC, the samples were prepared in triplicate and the mean value of absorbance was obtained.

3. *In vitro* assays

Four mature Merino sheep (body weight 49.4±4.23 kg) fitted with a permanent ruminal cannula were used for the extraction of rumen fluid to carry out the in vitro incubations of the substrate material. Animals were fed on 1 kg of lucerne hay once a day and had free access to water and mineral/vitamin licks. A sample of rumen fluid was withdrawn prior to morning feeding, transferred into thermos flasks and taken immediately to the laboratory. Rumen fluid from the four sheep was mixed, strained through various layers of cheesecloth and kept at 39°C under a CO_2 atmosphere. For *in vitro* dry matter digestibility, the technique proposed by Van Soest *et al.* (1966) was followed. A culture medium containing macro– and micro-mineral solutions, resazurin and a bicarbonate buffer solution was prepared as described by Van Soest *et al*. (1966). The medium was kept at 39°C and saturated with CO_2. Rumen fluid was then diluted into the medium in the proportion 1:5 (v/v). Samples (250 mg) were weighed out into artificial fibre bags (size 5cm × 5cm, pore size 20m) which were sealed with heat and placed in incubation jars (two). Each jar is a 5L glass recipient with a plastic lid provided with a single-way valve which avoids the accumulation of fermentation gases.

Each incubation jar was filled with 2L of the buffered rumen fluid transferred anaerobically and closed with the lid, mixing the contents thoroughly. The jars were then placed in a revolving incubator (Ankom Daisy II digestion system, ANKOM Technology Corp., Fairport, NY, USA) at 39°C, with continuous rotation to facilitate the effective immersion of the bags in the rumen fluid. After 48h of incubation in buffered rumen fluid, incubated bags were gently rinsed in cold water and oven dried (48 h). The residue was then after weight in order to determine the apparent degradability (Deg). After weighing, bags with their residues were submitted to an extraction with a neutral detergent solution at 100°C during 1h as described by Van Soest *et al*. (1966), in order to remove bacterial cell walls and other endogenous products, and therefore can be considered a determination of the true in vitro digestibility (TID). This technique was performed in three replicates (three bags/sample). A total of 6 repetitions were performed.

4. Statistical analysis

One-way analysis of variance (Steel and Torrie, 1980) was carried out with phenolic and flavonoid compounds and in vitro dry matter digestibility (IDM) data to examine the differences among sampling regions. The statistical significance of the differences between means was evaluated using the Duncan test. Differences are considered significant for $P<0.05$

III – Results and discussion

Data on the chemical composition of leaves of *A. iva* collected from different regions is given in Table 1. The crude ash content of leave samples ranged between 15.2 (Mograne) and 24.3% (Nabeul). Likewise, the crude protein content (CP) ranged between 8.9 (Dogga) and 14.7% DM (Mograne). These differences between regions could be due to some external factors such as climatic conditions, soil and environment. As this study is the first one focused on the nutritional value of *A. iva* in terms of chemical composition and dry matter digestibility, our results cannot be compared with others but could represent a reference for further studies looking for the same purpose. Anyway, it appears that *A. iva* leaves contain enough CP to meet the minimum CP requirement (8% of DM) for optimal microbial function and it may be important for animal maintenance in critical periods. The ether extract (EE) content of the sampled leaves ranged in narrow interval (1.1– 1.6%). These low levels could reflect low essential oil contents of this plant. Samples from Mograne locality revealed the lowest NDF (29.3% DM) and ADF (22.3% DM), however those from Nabeul locality revealed the highest NDF and ADF contents, 37.0 and 30.1% DM, respectively. This tendency looks to be opposite to that followed by CP. The lowest true *in vitro* dry matter digestibility (TID) was recorded for sample from Nabeul locality (67.9% DM) and the highest one for samples from Mograne locality (79.3% DM). Irrespectively of the sampling locality, DIV was always lower than 80% DM) probably due to the high phenolic compounds of *A. iva* species.

Table 1. Chemical composition (%DM) and true in vitro dry matter digestibility (TID, % DM) of *Ajuga iva* leaves sampled from different localities

	DM	MM	EE	CP	NDF	ADF	ADL	TID
Dogga	89.5	16.9	1.6	8.9	30.6	232	5.3	77.6 ± 1.48
Mograne	90.0	15.2	1.3	14.7	29.3	22.2	5.7	79.3 ± 1.63
Nabeul	90.2	24.3	1.1	11.6	37.0	30.1	5.0	67.9 ± 3.90

Various studies showed that phenolic compounds are widely distributed in the *Ajuga* species and these compounds could contribute to their antioxidant activity (Toiu *et al*., 2019). In the present study, a preliminary comparative overview of the total phenolic and flavonoid contents (TPC and TFC respectively) of the different extracts of *A.iva leaves* collected from different localities is pre-

sented (Table 2). In Tunisia phenolic and flavonoid contents were determined for the first time by Makni *et al.* (2013) using different solvents for extraction. They found that extraction with methanol (ME) and water (AE) resulted in the highest amount of total extractable compounds. In our present study the TPC varied between 10.1 and 12.4 GAE/g DM for AE and 13.6 and 14.0 GAE/g for ME. These values are lower than those reported by Makni *et al*. (2013) on whole fresh plant collected from Sidi Bouzid area.

Table 2. Total phenolic (TPC) and total flavonoid contents (TFC) in aqueous (AE) and methanol extract (ME) of *Ajuga iva* leaves sampled from different localities

Extract	Total phenolic compounds (GAE/d DM)			Total flavonoid compounds (QE/gDM)		
	Dogga	Mograne	Nabeul	Dogga	Mograne	Nabeul
Aqueous	11.8a	10.1b	12.4a	7.6b	6.5a	6.2b
Methanol	13.6a	14.0a	13.8a	12.6a	8.6a	12.1a

In the same column, values with different letter are significantly different (P<0.05).

Likewise highest values of TFC were recorded for ME. The combination of organic solvent and water facilitates the extraction of all compounds that are soluble in both water and organic solvents. Moreover differences were significant (P<0.05) for Dogga and Nabeul localities. It appears that the amount of secondary metabolites in plants depend on biological factors as well as on edaphic and environmental conditions. Results reported by Makni *et al*. (2013) confirmed antibacterial and antifungal activity of the whole plant of *A. iva.* Therefore, it could be suggested that consumption of *A. iva* by grazing animals would help to control some bacterial diseases.

IV – Conclusion

This study could be a starting point to justify the pastoral use of this plant by small ruminant in mountainous regions in Tunisia. Further studies on tannin contents and biochemical activities of the aereal parts of the plant should be studied. Likewise, addition of *A. iva* extract at different doses to animal diet and its effect on digestion of the total ration should be assessed.

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Content of polyphenolic compounds in *Melilotus officinalis* ecotypes from Morocco

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Abstract. Twenty ecotypes of yellow *Melilotus officinalis* from the north-west pastures of Morocco have been cultivated in the experimental station of the National Institute of Agronomic Research of Tangier. The samples were collected during the vegetative, budding and flowering stages in order to evaluate the phenolic content. Phenolic content of the ecotypes collection varied significantly with the maturation stage and the ecotype origin. Total phenols (TP) increased significantly from 2.14% dry mater (DM) at the vegetative stage to 2.37% DM at the flowering stage (P<0.01). Total tannins (TT) increased from 0.71 % DM at vegetative stahe to 0.78% DM at the budding stage and then decreased to 0.67% DM in the flowering stage. In contrast, the condensed tannins content (CT) of the collection decreased significantly from 0.10 at the vegetative stateto 0.04% DM (P<0.001) at the flowering maturation stage. In addition, the content of TP and TT varied significantly between ecotypes, from 2.01 to 2.69 % DM (P<0.001) and from 0.44 to 1.15% DM (P<0.001), respectively. The high content of CT was obtained at the vegetative stage with 0.10% DM.

Keywords. *Melilotus officinalis* – Ecotype – Phenols – Tannins.

Teneur en composés phénoliques d'une collection d'écotypes de* Melilotus officinalis *de la région Nord-Ouest du Maroc

Résumé. *Vingt écotypes de Mélilot* (Melilotus officinalis) *des pâturages du Nord-Ouest du Maroc ont été installés dans la station expérimentale de l'INRA à Tanger. Des fauches ont été réalisées, au stade végétatif, bourgeonnement et floraison, afin d'évaluer la composition en phénols et tanins. Le résultat montre que Melilotus officinalis est caractérisé par des teneurs modérées en composés phénoliques extractibles. La concentration de ces composés varie significativement avec le stade de maturation et aussi en fonction de l'origine de l'écotype. En effet, en allant du stade végétatif à la floraison, la teneur en phénols totaux (PT) augmente de 2,14% à 2,37% MS, alors que la teneur en tanins totaux (TT) augmente de 0,71% MS à 0,78% MS au stade bourgeonnement puis elle chute à la floraison 0,67% MS. En revanche, la teneur en tanins condensés (TC) diminue de 0,10 %MS à 0,04% MS. Selon les écotypes, la teneur en PT et TT varie significativement de 2,69% MS à 2,01% MS et 1,15% MS à 0,44% MS respectivement. Les teneurs maximales obtenues en TC sont obtenues au stade végétatif avec 0,10% MS. Ces concentrations sont au-dessous de la limite minimale (2% en TC) qui pourrait affecter la valeur nutritive du fourrage et la santé de l'animal.*

Mots-clés. Melilotus officinalis – *Écotypes – Phénols – Tanins.*

I – Introduction

Technical, economic and environmental pressures limit goat's production in Morocco; therefore, the valorization of not exploited locally feeding resources is a necessary option to mitigate these issues.

The prospects of *Melilotus officinalis* (yellow sweet clover) in the Moroccan North-West has led to a collection of 20 ecotypes. This study helped afterward to analyze the content of phenolic compounds according to the genetic variation of these ecotypes. The phenolic compounds are known for their

anti-nutritional proprieties, which influence the production of milk and meat; but in exchange, they are able to improve quality of the unsaturated fatty acids (Ayadi, 2014). A study revealed that *Melilotus* sp. contain higher contents of phenols and flavonoids than condensed tannins (Olgica *et al*., 2015).

II – Materials and methods

Twenty ecotypes of *Melilotus officinalis* were established at the experimental field of Boukhalef. Green matter samples were collected at the vegetative, budding and flowering stages. Samples were dried at 60°C then ground through a 1 mm sieve (AOAC, 1997). The samples were analyzed for total phenols (TP), total tannins (TT) and condensed tannins (CT). The determination of phenols and total tannins was accomplished according to the method of Makkar *et al*. (1993) by using the Folin Ciocalteu's reactive. Wave's length of 725 nm was used on a visible spectrophotometer to measure the absorbance of the samples. The condensed tannin's absorbance was measured at 550 nm following the method of HCl-Butanol (Porter *et al*., 1986). The determination of the phenolic compounds content was carried out by using the linear calibration curve (y=ax) which was drawn according to the spectral answer of solutions composing different concentration of tannic acid.

The effect of the growth plant and ecotype on studied parameters was analyzed with software SAS (version 9, 2004) by using GLM's procedure. The multiple comparison of average was carried out using the test "Last Square Deviation".

III – Results and discussion

The ecotypes studied differed significantly (P<0.001) on TP contents. E19 was associated with the higher value at 2.69% DM, while E17 and E18 with the lowest values at 2.04% and 2.01%DM respectively (Fig. 1).

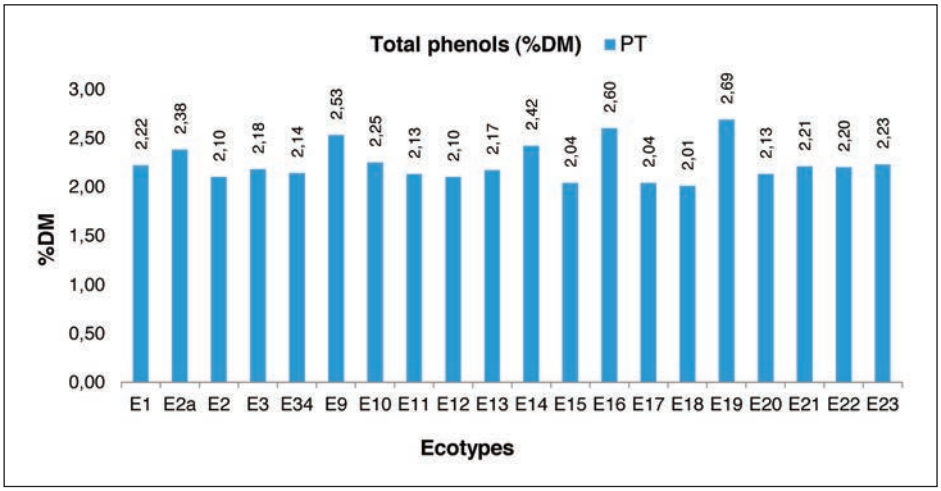

Fig. 1. Total phenols (TP) content of a collection of yellow sweet clover ecotypes.

The effect of ecotype on TTs content was also highly significant (P<0.001). The highest values were recorded for E14 and E16 at 1.01% DM and 1.14% DM respectively, while the lowest values were for E17 and E20 at 0.49% DM and 0.44%DM respectively (Fig. 2).

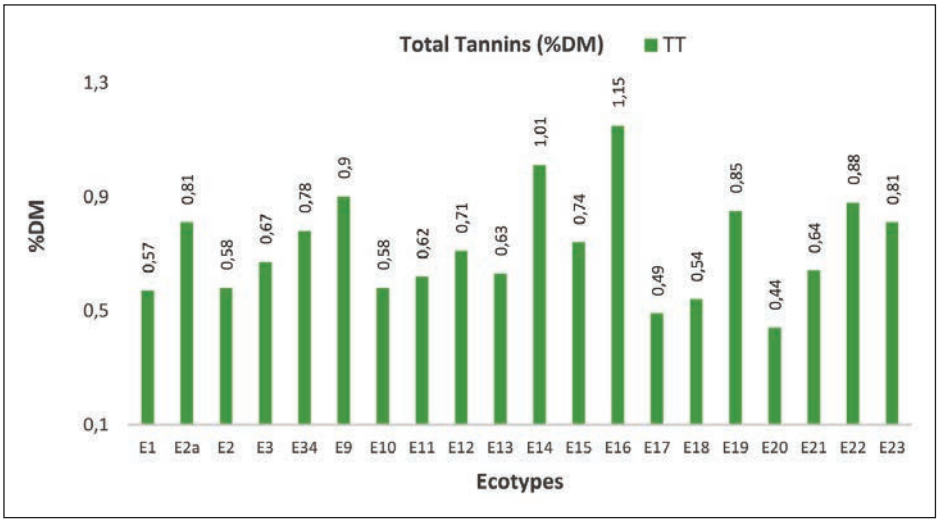

Fig. 2. Total tannins (TT) content of a collection of yellow sweet clover ecotypes.

The yellow sweet clover ecotypes studied had low CT contents (0.4 to 0.14% DM), but the variability of the CT's content between ecotypes was significant ($P<0.05$). Indeed, three ecotypes stand out according to their CT's content. The majority (45% of the studied ecotypes) had a medium CT's content, which varied between 0.07 and 0.08% DM. The highest CT content (0.1 to 0.14% DM) was represented by a 15% of the ecotypes (Fig. 3).

The average content CT obtained was 0.07% DM, a similar value to that recorded by Hamacher *et al*. (2013) which reported a close CT value (0.06% MS). The ecotypes which recorded the lowest values are E18 and E21 with 0.04 and 0.05% DM respectively. The maximum contents of CT were obtained with only 3/20 ecotypes (E15, E22, E23) with an average of 0.12% DM.

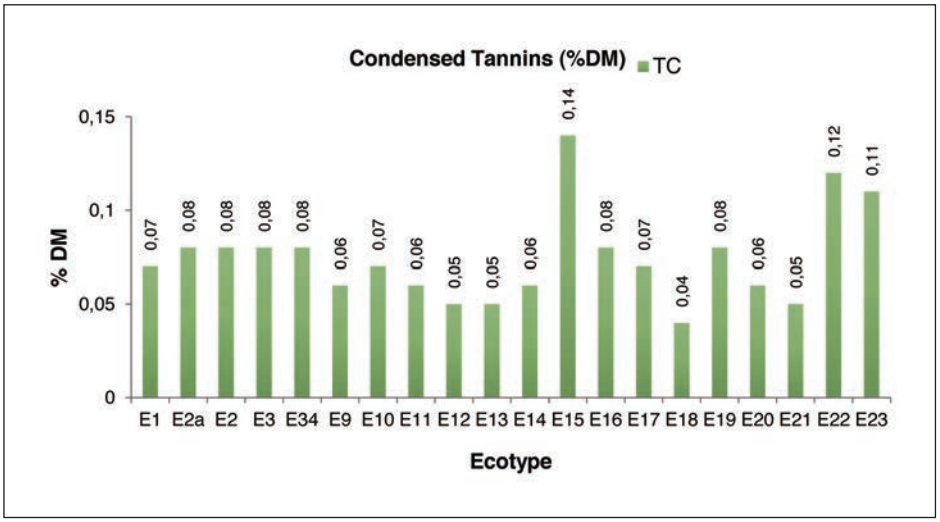

Fig. 3. Condensed tannins (CT) content of a collection of yellow sweet clover ecotypes.

The growth stage of plants had a significant effect on TP and CT (P<0.001). The TP followed an ascending trend according to the development stage; they increased from 2.14% DM at the vegetative stage up to 2.37% DM at the flowering stage. TT increased from the vegetative (0.71 %DM) to the budding stage (0.78% DM) and then decreased to 0.67 %DM at flowering. However, the CT decreased continuously with the development of the plants, where contents dropped from 0.10% DM at the vegetative stage up to 0.04% DM at the flowering stage. Macheix *et al*. (1991) reported that the flowering stage had the lowest CT value, since the phenolic compounds are more important in the young plants. In general, whatever the stage of growth, the level of the CT amount recorded by *Melilotus officinalis* cannot generate a negative effect on the digestibility of proteins. Indeed, the study made by Jayanegara *et al*. (2012) revealed that a CT content lower than 2% DM does not have any effect on rumen microbial activity (anti-methanogenic effects).

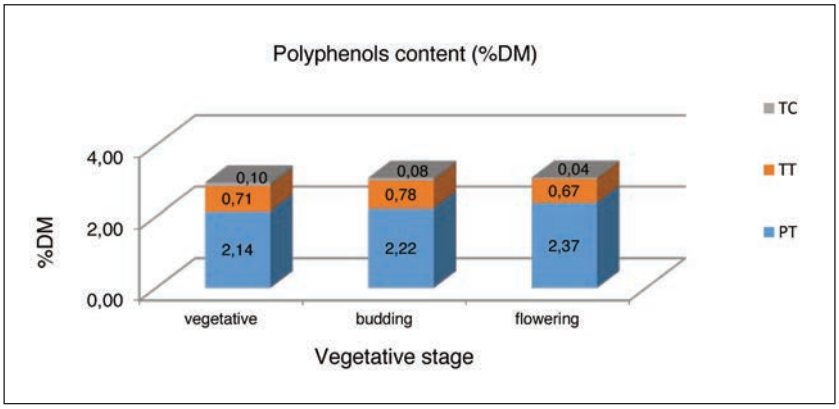

Fig. 4. Polyphenols content of yellow sweet clover by stage of growth.

The average content total phenols in the *Melilotus* ecotypes studied was 2.24% DM. This content is higher than the one found by Hamacher *et al*. (2013) who reported a content of 1.59% DM. However it remains lower than that recorded in Sulla, whose content reaches 2.6% DM (Errassi *et al*., 2018). The increase of total phenols from the vegetative to the flowering stage can be explained by the decline to the soil nitrogen contents (Mohd *et al*., 2011).

IV – Conclusions

The phenolic compounds are known for their anti-nutritional properties, but the collection of the yellow *Melilotus* ecotypes from the Morroccan North-West is characterized by relatively low contents. The maximum contents of condensed and total tannins of the studied ecotypes hardly exceed 0.14 and 1.15% DM respectively. Most ecotypes contained low condensed tannins varying from 0.06 to 0.08% DM. This result supports the interest on the quality of yellow sweet clover as a fodder resource in terms of contents in anti-nutritional substances.

The concentration of the total phenolic compounds in the *Melilotus* ecotypes studied showed a decline with the advance of the growth stage. For the condensed tannins, the variation of their content is negligible whatever the stage of development or the source of the seed.

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Characterization of bitter vetch (*Vicia ervilia* (L.) Willd.) landraces conserved on-farm in Lemnos Island

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Abstract. Lemnos Island presents a rich biodiversity in legume genetic resources both in wild and cultivated species that provide ecological benefits and have high nutritious value as food and feed. Among the cultivated genetic material that is conserved on farms, landraces of a neglected fodder crop, bitter vetch, have evolved under harsh climatic conditions when grown under traditional farmer practices. Lemnian bitter vetch landraces, along with other populations collected on farms and landraces with Greek origin conserved *ex situ* were characterized using 24 agro-morphological traits and the phenotypic diversity among and within populations was estimated. The mean total phenotypic diversity of the whole collection was H_T=0.52 while the mean phenotypic diversity among populations studied (G_{ST}) was 0.31. A significant variability was revealed among Lemnian populations regarding their morphological and agronomical traits. Applying Discriminant Analysis the three landraces from Lemnos were clustered in separate groups and differentiated from each other mainly due to their days to flowering, days to pod setting and their productivity. On-farm cultivated bitter vetch landraces of Lemnos consist therefore a variable genetic material and on farm management seems to be a valuable conservation practice in the case of this isolated island.

Keywords. Conservation practices – Diversity – Greece – Lemnos Island – Neglected crop.

Caractérisation de variétés de vesce amère à la ferme* (Vicia ervilia *(L.) Willd.) De l'île de Lemnos

Résumé. *L'île de Lemnos présente une riche biodiversité en ressources génétiques de légumineuses, tant en espèces sauvages que cultivées, qui présente des avantages écologiques. Ces espèces ont une valeur nutritive élevée pour l'alimentation humaine et animale. Parmi le matériel génétique cultivé conservé dans les fermes, les races locales d'une culture fourragère négligée (la vesce amère) ont été développées sous des conditions climatiques difficiles et cultivées selon les pratiques paysannes traditionnelles. Dans la présente étude sur les races locales de vesce amère de Lemnos, des populations provenant de fermes et d'autres populations locales d'origine grecque, conservées* ex situ*, ont été recueillies. Celles-ci ont été caractérisées sur la base de 24 traits agro-morphologiques et la diversité phénotypique au sein des populations a été estimée. La diversité phénotypique totale moyenne était H_T = 0,52 tandis que la diversité phénotypique moyenne parmi les populations étudiées (G_{ST}) était de 0,31. Une variabilité significative a été révélée parmi les populations de Lemnos en ce qui concerne leurs traits morphologiques et agronomiques. En appliquant l'analyse discriminante, les trois races locales de Lemnos ont été regroupées en différents groupes et différenciées les unes des autres, principalement en fonction de leur date de floraison, de la date de formation des gousses et leur productivité. Les variétés locales de vesce amère de Lemnos cultivées à la ferme constituent donc un matériel génétique variable. Ainsi, la gestion à la ferme semble être une pratique de conservation précieux dans le cas de cette île isolée.*

Mots-clés. *Pratiques de conservation – Diversité – Grèce – Île de Lemnos – Culture négligée.*

I – Introduction

Bitter vetch (*Vicia ervilia* (L.) Willd.) is one of the oldest cultivated grain legume crops in the Mediterranean region. Although bitter vetch was a common crop in the past, it is recently considered a neglected crop (López Bellido, 1994). However, bitter vetch populations are still cultivated on farms

(Thomas *et al.,* 2012; El Fatehi *et al.,* 2016). In Greece, bitter vetch landrace populations can still be found in areas such as isolated islands conserved by individual farmers mainly as a heritage element.

Lemnos is a North Aegean Island (Greece) rich in wild and cultivated plant species that preserves its agricultural character. Among the wild plant species recorded, 19% are legumes (Panitsa *et al*., 2018), while agrobiodiversity is still maintained in cultivated pulses and fodder legumes including also bitter vetch landraces (Thomas *et al.*, 2012, Bebeli *et al*., unpublished data). Landrace populations have evolved overtime under farmers' traditional cultivation practices and natural selection pressure (Terzopoulos and Bebeli, 2010), present local adaptability and are characterized by various levels of variability which can be measured using morphological descriptors. The study of landrace populations genetic diversity is prerequisite for their effective conservation and exploitation. Therefore the aim of the present study was the characterization and diversity assessment of three Lemnian bitter vetch landraces along with other on farm cultivated and *ex situ* preserved accessions.

II – Materials and methods

1. Plant material and experimental design

Three Lemnian landraces (AUA7, AUA9 and AUA10) (Fig. 1) were characterized and subjected to analysis of phenotypic diversity, along with six other Greek on farm collected landraces, thirty-two landrace material originated from Greece, obtained from the Genebank of IPK Gaterslaben and eight accessions of foreign origin, obtained from the Genebank of USDA. The experiment was carried out at Agricultural University of Athens, Greece (N 37°59'10'', E 23°42'29'', altitude 24 m). A randomized complete block design with two replications was applied. Plants spaced at 30 cm from row to row and plant to plant distance. Ten plants per population of each replication were measured (Livanios *et al*., 2017).

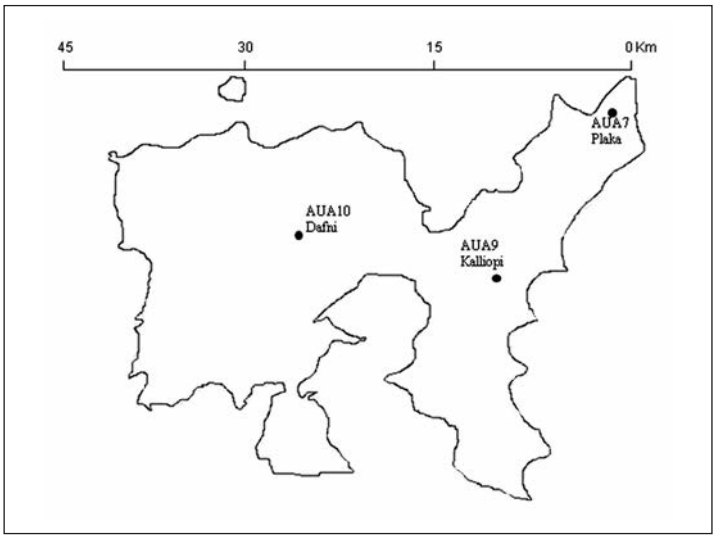

Fig. 1. Lemnos Island, representation of the three sites where Lemnian landraces were collected.

2. Agro-morphological traits

Twenty-four morphological and agronomical traits were measured based on common vetch (*Vicia sativa* L.) descriptors list (UPOV, 2011) and lentil (*Lens culinaris* Medic.) descriptors list (IBPGR and ICARDA, 1985). Measurements were taken throughout the life cycle of the plants and included morphological characters traits recorded at the vegetative and reproductive stage. In addition traits related to seed yield and seed morphology were recorded (Livanios *et al.,* 2017).

3. Statistical analysis

Data from all continuous traits were transformed to ordinal by dividing their range into equal classes forming discrete ranks (Livanios *et al.,* 2017). Class frequencies were used to describe and assess Lemnian landraces and the rest of the bitter vetch accessions diversity (Nei, 1973). For each trait, total phenotypic diversity (H_T), inter– population (G_{ST}), intra– population phenotypic diversity (H_S), its average across all populations (H_S mean), as well as mean phenotypic diversity within each Lemnian landrace across all traits (H_P mean) were calculated according to Terzopoulos and Bebeli (2010). Comparisons of Lemnian landraces with all populations (H_P mean) were carried out (HSD, $p \leq 0.05$) using the statistical software JMP-8. Finally, Discriminant analysis was applied in order to distinguish the bitter vetch populations studied and define the uniqueness of each one of the three Lemnian landraces.

III – Results and discussion

Lemnos has still today a wealth of crop landraces due to its geographical position, and its long agricultural history. The survival of the bitter vetch landrace populations on farm in Lemnos is a very interesting case, since this crop is considered neglected and rare (Thomas *et al.,* 2012, Bebeli *et al.*, unpublished data 2019). All Lemnian landraces were characterized by existence of red pigmentation in plants stems, absence of pigmentation in their leaflets, production ofa small number of primary branches (1 to 5) and a small amount of seeds per plant (1 to 402 seeds).

However, diversity was observed among them regarding many traits such as their flower color, with AUA10 to present high intra-population variability, with white, white-purple and white-pink flowers. On the contrary AUA7 and AUA9 presented only white-purple flowers. AUA10 was also differentiated due to its early flowering (98-113 days) and maturation (120-134 days) in comparison to the other two Lemnian landraces that presented 114-129 days and 135-149 days, respectively. In addition variability was observed among the three landraces based on their plant height, as AUA7 had shorter plants reaching only 27 cm height compared to AUA9 and AUA10 that their plant height ranged from 28 to 42 cm. AUA10 proved to be the most productive one among the three Lemnian landraces due to its higher number of pods and seeds per plant with 110.3 and 289.5 on average, respectively. AUA10 also resulted in a higher seed weight per plant, reaching on average 10.88 g of seeds per plant, while AUA7 and AUA9 had on average 5.81 and 7.27 g of seeds per plant. On the other hand, AUA7 was the Lemnian landrace that resulted in higher stems dry weight, presenting a mean of 18 g. Applying Discriminant Analysis in the whole collection of landraces studied, each one of the three landraces originated from Lemnos was assigned to a different group, confirming the diversity present in Lemnos bitter vetch germplasm.

The mean total phenotypic diversity of the whole collection was HT=0.52 while the mean phenotypic diversity among populations studied (G_{ST}) was 0.31. Regarding the whole collection, the mean phenotypic diversity within each population across all traits ranged between 0.27 and 0.47 with an average of 0.36. The three Lemnian landraces presented average values (0.36 for AUA7 and AUA10, 0.37 for AUA9) similar to other populations (data not shown). A large variability was confirmed therefore among the three Lemnian landraces that developed different agro– morphological traits under their adaptation, and the various cultivation practices and selection implemented by farmers.

IV – Conclusions

The utilization of landrace populations by farmers is critical, as it will help to ensure that genetic resources will be available for future generations through on-farm conservation. A valuable collection of bitter vetch landraces conserved on farm was identified. Lemnian landraces were characterized by similar levels of mean phenotypic diversity within each population across all traits compared to other accessions. Cultivation of crop landrace populations continuously, even in small fields for preservation of cultural heritage, reveals conservation of bitter vetch diversity in the Island of Lemnos and therefore should be encouraged and rewarded.

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Proposal of some promising native species for forage crops in the Saharan areas and the Eastern High Atlas

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Abstract. Natural pastures are the initial food base for cattle, goats and sheep. Forage exploitation species allowing an increase of the animal productions must pass initially by the identification of the local existing flora. As part of our various surveys and studies on pre-Saharan pastures, we have been able to identify a number of promising species based on their productivity and palatability. These species could be used as fodder crops in the Saharan areas and the Eastern High Atlas. We describe in this paper eight species belonging to the two great families of fabaceae and poaceae. Among these eight species, one is an endemic of Morocco.

Keywords. Autochtone plants – Forage crops – Palatability – Saharan areas.

Proposition d'espèces indigènes prometteuses pour les cultures fourragères dans les zones sahariennes et le Haut Atlas oriental

Résumé. *Les pâturages naturels constituent la base alimentaire initiale des bovins, des caprins et des ovins. L'exploitation des espèces fourragères permettant une augmentation des productions animales doit passer dans un premier temps par l'identification de la flore existant localement. Dans le cadre de nos différentes prospections et études sur les pâturages présahariens, nous avons pu identifier un certain nombre d'espèces prometteuses sur la base de leur productivité et appétibilité. Ces espèces peuvent être utilisées comme cultures fourragères dans les zones sahariennes et le Haut Atlas oriental. Nous décrivons dans cet article huit espèces appartenant aux deux grandes familles des fabacées et graminées. Parmi ces huit espèces, une endémique du Maroc.*

Mots-clés. *Espèces autochtones – Fourrage – Appétibilité – Zones sahariennes.*

I – Introduction

Rangelands of Morocco are homes of biodiversity and main feed resources for livestock. Arid rangelands-based livestock production systems face the challenge of producing more meat and milk to meet increasing demands and achieve this using fewer resources. We found in these areas many herbaceous and shrubby plants that are consumed by ruminants and represent possible potential as forage crops to overcome the scarcity of resources and the increasing number of livestock. The objective of this paper is to describe eight potential species for forage farming identified in the south-east of arid rangelands in Morocco.

II – Description of the species

1. *Lupinus tassilicus* Maire

Lupins are forage legumes commonly used as natural green manure. They are also used for food and feed thanks to their high protein content (Guillemand, 1999). The genus Lupinus belongs to the fabaceae family and includes about 267 species from the Americas, Europe, and North Africa

(Drummond *et al.,* 2012). Only six species are spontaneous in Morocco. Among these six species, a particularly interesting species capable of colonizing the sandy and poor rocky lands of Saharan Morocco and the Anti-atlas, is *Lupinus tassilicus* Maire (vernacular name: Oum Kfifat). This plant was called by ancient "the golden rose of the sands" (Dahi, 2008) and it is adapted to the arid climate. It is an annual plant of 30-50 cm, unicaules, villous on the lower surface and glabrous on the upper surface. The leaves are long petiolate, palmately compound with 9-11 oblong-obovate leaflets; stipules welded to petiole. Dark blue flowers briefly pedicellate (3 mm) fairly close in raceme little interrupted, provided with a linear-lanceolate bract and 2 lateral protective leaves opposite to the lateral sinuses of the calyx. Blue corolla, exceeding the calyx. Stamens 10; the filament welded into a closed glabrous tube; Anthers basifixed longer than dorsifixed. Ovary silky, sessile; glabrous style. Pod compressed ± villous with a wavy structure of 2-5 large seeds, filling the whole cavity of the pod. It is a plant less appreciated by camels and sheep prefer to eat fruit. It's grows naturally on sandy well-aerated soil. Neverless, the nutritive value should be studied.

2. *Cullen plicatum* (Delile) C.H. Stirton (vernacular name: Tatrâret)

Cullen is a genus of dicotyledonous plants of the family Fabaceae, subfamily Faboideae, native to Africa, Asia and Australia, which includes 13 accepted species. It is an herbaceous green herb, perennial, covered with white hairs, very short and appressed. Stems and twigs striated. The leaves are alternate, stipulated, long petiolate, greyish lanceolate trifoliate; median leaflets not more than 2 (3) cm long and about 4 times longer than wide. The stipules are entire margin, free and persistent. The leaflets are petiolate, sinuate-crenellated margins. The flowers are small, 3-5 mm long with pink corolla, short pedicel, arranged in 2 or 3 spike-like, raceme elongated, axillary, long pedunculated. The fruit is ovoid, warty, monosperm, indehiscent. Axis of fruiting bunches persist after falling of the fruits. It is a plant that colonizes especially the beds of valleys, the regs and sandy, stony soils of desert Morocco. This species contains 10.3% of the protein and is consumed mainly by camels (Kadi and Zrimi, 2016).

3. *Bituminaria bituminosa* (L.) Stirton (Resin clover)

Bituminous Psoralea (asphalt clover) is a dicotyledonous perennial plant of the Fabaceae family widely distributed in the countries of the Mediterranean basin and which could potentially serve as a forage crop in Mediterranean grasslands (Sternberg *et al*., 2006). It has been traditionally used to feed goats in the Canary Islands (Ventura *et al*., 2004) and is supposed to tolerate intensive pastures (Sternberg *et al*., 2006). There is a growing international interest in the use of *B. bituminosa* as forage crop, currently used as a model plant in forage production programs in Australia (Real and Verbyla 2010). This species grows abundantly in several regions of Morocco and in desert parts. It is a perennial herb that forms a tuft of 50 cm to 1.5 m high, pubescent-glandular, erect. The stems are long, thin and not very branched. The leaves are trifoliate with three thin elliptical or lanceolate leaflets, entire, punctate-glandular and sparsely hairy. A characteristic feature that easily distinguishes the plant is the smell coming from crushed stems and leaves. The stipules are free, linear acuminate. The bluish flowers are held a long peduncle (2-4 times longer than the leaf). They are gathered into a tight, rounded false capitule with 10-15 semi-spherical heads (packed raceme). The keel is white and the wings, longer than the keel, have a beautiful lilac color. The calyx is hairy, bell-shaped, with 5 unequally long teeth, lanceolate-linear, equaling the tube; banner oblong, exceeding the wings and the keel obtuse. The stamens are diadelphous and the stigma in head. The flowers, rich in nectar, are attractive to pollinators and many useful insects. The fruits are pods of about 2 cm. The pod is oval-compressed, beak-shaped, 2 times longer, not stipitate, hairy, indehiscent, single-seeded. Seed nearly spherical and dark brown, is about 5mm in size. It is a species that can be disseminated abundantly on stony or on recently labored soil. Several varieties have been described in Spain. The field of research in Morocco is still blank, a new endemic species

has just been added to the list of Morocco (*Bituminaria antiatlantica*) previously described by Maire as variety of *Bituminaria Bituminos*a (Brullo *et al.,* 2017). The level of drought tolerance varied according to the variety. The 'albomarginata' is one of the most drought tolerant variety according to Martinez-Fernández *et al*. (2010). This species should be developed in Morocco as forage crop.

4. *Vicia onobrychioides* L.

Vicia is a genus of dicotyledonous plants of the Fabaceae family, subfamily Faboideae, with near-cosmopolitan distribution, which includes about 200 accepted species. This is the genus of vetches, beans and fababeans. False Sparrow Vetch or False Sainfoin (*Vicia onobrychioides*) is an upright or climbing herbaceous of montain with paripinnate leaves, composed of 4-8 lanceolate leaflets, 1-4 mm wide, obtuse, mucronate and terminated by a tendril that allows them to climb by hanging on nearby plants. The stipules are toothed or incised. The purple flowers (1.8 to 2.5 cm) –with a long corolla 15-20 mm, keel and wings often paler– are grouped by six to twelve in cowardly raceme, longer than the corresponding leaf. Calyx with unequal teeth, the lowers ones are longer. Podsare flattened, generally pendulous, glabrous, 3.5-6 cm long, 6-10-seeds. It flowers in June in hot and dry places, mainly near meadows and matorrals, up to 2200 m.

5. *Hedysarum boveanum* subsp. europaeum Guitt. & Kerguélen

The genus *Hedysarum* L. (Fabaceae: Hedysareae) consists of about 160 species of perennial herbs to rarely shrublets. It mainly distributes in temperate Eurasia, with a few species in North Africa and North America (Choi and Ohashi, 2003). Some *Hedysarum* species are good forages (Bonanno *et al*., 2010, Kadi *et al*., 2011). Hedysarum species adapt to various habitats in temperate forests, steppes and alpine regions. Dwarf Sainfoin of Europe (*Hedysarum boveanum* subsp. *Europaeum*) is a suffrutescent plant with glabrous stems, whitish and slightly pubescent (applied hairs) with a height of 15 to 50 cm. Imparipinnate leaves with 7-15 pairs of linear to oblong leaflets slightly folded, glabrous above and hairy beneath. The stipules are scabrous welded and amplexicaules. Inflorescence are in elongated raceme containing up to 20 flowers on peduncles exceeding adjacent leaves. The flowers are bright pink. Calyx 4 to 6 mm, pubescent, with teeth shorter than the tube, tinged with purple. Corolla 13-17 mm, keel (10) 11-18(20) mm, usually much longer than the banner. The fruit is glabrous or slightly pubescent, usually spiny, rarely smooth or tubercular, with (1) 2-4 segments. This plant is found in several places in the oriental High Atlas of Morocco but also in other places of Morocco (Rif and Middle Atlas) (Fennane and Ibn Tattou, 2007).

6. *Onobrychis Kabylica* (Bornm.) Sirj

Onobrychis is one of the most difficult genus to study. We found a lot of confusion and contradiction in the *Onobrychis* taxonomy. Guner *et al*. (2000) estimated that 54 species can be identified in the *Onobrychis* genus and are divided into 5 sections. Aktoklu (1995) (in Akçelik *et al*., 2012) reports that the genus is represented by 162 species of which 27 are endemic to Turkey. The sainfoin is an herbaceous plants of the Fabaceae family; some species such as *Onobrychis viciifolia* are grown as fodder plants. Kabylie sainfoins is a perennial herb with composed leaves, imparipinnate, formed up to 10 pairs of leaflets. 2 scarious stipules are always free. The flowers are pink grouped in elongated axillary raceme; The calyx is campanulate, with 5 subequal teeth. The corolla is pink; the banner is pubescent on the back, the keel is obtuse-truncated, almost straight with small wings. The androecium is diadelphous (9 + 1) and the filament is dilated at the top. The fruit is an indehiscent pod with 2 rows of marginal spines and a broadly-winged vertical crest. It is a very rare plant and very localized in the Eastern High Atlas.(Taxontaxon critically endangered in Morocco).

7. *Brachypodium atlanticum* Dobignard

The grasses family (Poaceae) includes the most important crop plants for human and animal nutrition and includes several subfamilies such as Pooideae (wheat, barley and oats), Ehrhartoideae (rice) and Panicoideae (maize, sorghum, sugar caneand millet). The genus *Brachypodium* belongs to the tribe Brachypodieae, a sister tribe of Triticeae in the subfamily Pooideae (Mochida and Shinozaki 2013). *Brachypodium* and wheat diverged from a common ancestor 32 to 39 million years ago (IBI, 2010). *Brachypodium* (especially *B. distachyon*) More than 10 years ago, has been suggested as a model plant for molecular studies on C3 cereals thanks to: its simple diploid genome, its close phylogenetic links with other temperate grasses, its relative simplicity genetic transformation, its short life cycle and its simple growth needs (Bevan *et al* 2010, Brkljacic *et al* 2011, Mur *et al* 2011). *Brachypodium* is a relatively small genus with about 18 species distributed worldwide (Schippmann 1991; Catalan and Olmstead 2000, Catalan *et al.,* 2012). Among these 18 species *Brachypodium atlanticum* Dobignard is an endemic grass to Morocco with a very restricted distribution in the High Atlas of Morocco. It is a perennial with an ordinarily flag leaves of 0.5-0.7 mm diameter. The sheath is split to the base. The raceme is simple, spiciform. The spikelet is hairy very shortly pedicelled, cylindraceous, then ± compressed laterally, multiflores. The upper flowers are male. The rachole is ± fragile. The glumes are ciliated towards the margins and often have some hairs on the rounded back. The lemma is rounded on the back, usually aristate, long ciliated towards the margins and covered on the back with a ± appressed and dense villus hairs. The palea with pectinate-ciliated keel. Both lodicules are ± fimbriated or ± ciliated. The anthers equal or exceed the middle of the palea. The ovary is glabrous or short-haired; the styles are apical. The caryopsis loosely adheres to the palea, linear oblong, furrowed with linear hilar macule that occupying its entire length.

8. *Centropodia forsskalii* (Vahl) Cope

It is a hemicryptophyte (Raunkiaer 1934), with caespitose stems, one or more kneeed stubble, strong, distal and pubescent culm-internodes. The leaves are stark and glaucous. Leaf-blade surface ribbed; pubescent; Leaf-blade apex pungent. The lower leaves reduced to sheath, without blade or very small limb. Leaf-blade leaves up to 8 x 0.5 cm, attenuate callus; ligule reduced to a row of hairs of about 2 mm long. The sheath of the lower leaves with short and long hairs mixed. The inflorescence is a short contracted panicle (5-15 cm) embraced at base by subtending leaf. The flowers are cuneiform and fleshy. Spikelets are multiflores comprising 2-3 fertile pedunculate florets, lanceolate, 6-11 mm long. Rhachilla internodes elongated between glumes; definite. Floret callus evident; curved; 1 mm long; pubescent; pungent; disarticulating obliquely. The glumes are subequal 5-10 mm long, without keels, 7-9 – veined, with bands of whitish hairs between the veins, acute at the apex; the lower glume is elliptical with asperulous surface; upper glume lanceolate chartaceous; without keels. Lemma is bilobed, acuminate; 1 –awned. Principal lemma awn from a sinus; straight, or geniculate; 3-4 mm long overall. The anthers 3, 0.7-1.2 mm long. The fruit is a caryopsis with adherent pericarp. This species colonizes the deep sands of the Saharan regions and is able to take advantage of low rainfall.

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Agronomic assessment of a genotypes collection of *Melilotus officinalis*

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Abstract. This study is aimed to evaluate the agronomic performance of twenty ecotypes of yellow sweet clover which were collected from the North-West of Morocco and were cultivated in the experimental station of Boukhalef (Tangier). The samplings were realized during the vegetative, budding and flowering stages. The results showed that yellow sweet clover have a high production of dry matter. The dry matter yield (DMY), the leaves on steam report (LSR) and the stem's diameter (SD) depends significantly of the maturation stage and the origin of ecotypes. From the vegetative to the flowering stage, the DMY increased significantly from 6.54 to 10.59 t/ha (P<0.001), from 61.96 cm to 142.36 cm for plant height (P<0.001) and SD from 6.5 to 7.74 mm (P<0.001), while the LSR decreased significantly from 0.82 to 0.61 (P<0.001). Between the ecotypes, DMY, LSR and SD varied significantly from 14.81 t/ha (E34) to 4 t/ha (E3) (P<0.01), 1.18 (E3) and 0.6 (E1 and 9) (P<0.001), from 8.91 (E23) to 6.21 mm (E13) (P<0.01) respectively. The highest values of number of ramifications and foliar area were obtained in the flowering stage with 21.50 and 24.05 mm^2, respectively. The agronomic evaluation showed that the yellow sweet clover presents a sure interest as forage species for animals feeding.

Keywords. Yellow sweetclover – Ecotype – Harvest stage – Dry matter production.

Evaluation morphologique et agronomique d'une collection d'écotypes de mélilot jaune du nord ouest du Maroc

Résumé. *Vingt écotypes de mélilot* (Melilotus officinalis) *des pâturages du Nord-Ouest du Maroc ont été cultivés dans la station expérimentale de l'INRA. L'échantillonnage a été réalisé, au stade végétatif, bourgeonnement et floraison, afin de réaliser la caractérisation agronomique. Le résultat montre que* Melilotus officinalis *est caractérisé par une production en matière sèche importante. Le rendement en matière sèche, le rapport feuille sur tige et le diamètre de la tige varie significativement avec le stade de maturation et aussi en fonction de l'origine de l'écotype. En effet, en allant du stade végétatif à la floraison, le rendement en matière sèche augmente de 6,54 T/ha à 10,59 T/ha, de 61,96cm à 142,36cm pour la hauteur, 6,5 à 7,74mm pour le diamètre de la tige. En revanche, le rapport feuilles/tige RFT diminue de 0,82 à 0,61. Selon les écotypes, le rendement en matière sèche, le RFT et le diamètre de la tige varie significativement de 14,81 T/ha à 4 T/ha, de 1,18 à 0,6 et de 8,91mm à 6,21 mm respectivement. Les valeurs maximales de nombre de ramification et de l'espace foliaire sont obtenues à la floraison avec 21,50 et 24,05mm^2 respectivement. Melilotus officinalis se prête bien au pâturage et présente un intérêt certain dans l'alimentation animale.*

Mots-clés. *Mélilot – Ecotype – Stade de coupe – Rendement en matière sèche.*

I – Introduction

Melilotus officinalis, commonly called yellow sweet clover is an annual or bi-annual herbaceous leguminous plant (Fabaceae). It develops spontaneously in the natural pastures of North Morocco. It presents an interest as fodder, medicinal and aromatic plant and is cultivated elsewhere for the pasture and forage. The yellow sweet clover is a fodder with a good nutritional, offering a large amount of proteins and minerals. Plant height ranges from 1.2 to 1.5 m for the annual plants (Go-

plen et *al.*, 1984). This species shows a good adaptation to the environmental conditions of the North Western Morocco. It can constitute, in fact, a resource of great nutritive interest comparable with Persian and Egyptian clovers (Lahkim Bennani *et al.*, in this volume). The yellow sweet clover improves soils because of its much-ramified roots, which penetrate perfectly in the ground and absorb the non-assimilable nutritive substances by the radicular surface. These roots are also characterized by their fast decomposition that allows a better permeability of the ground. It is also characterized by its action supporting the increase in the content of organic matter and nitrogen of the soil (Goplen *et al.*, 1984). Considering the use of nutritive elements, *M. officinalis* is a very competitive species, (Jacob *et al.*, 2014). To preserve the genetic potential which is exposed to a strong erosion, in 2017, a prospection and collection program of local yellow sweet clover started in North Western Morocco (Tangier), aimed to create of a collection of ecotypes (Ayadi et *al.*, 2017). A field experiment was carried out with the objective to evaluate some morphological traits and the potential forage production, in order to select the most promising ecotypes.

II – Materials and methods

The seeds of 20 ecotypes of *M. officinalis* collected in 2017 from various ecological areas of North Western Morocco were sown in the Experimental Field of Boukhalef on 13th November 2017. Each ecotype was established on a plot of 10x2 m with 1m separation from each other. The plot was subdivided in 5 lines; each line is a replication, with a line space of 40 cm. Each line was sown with an amount of 10 g corresponding to a seed dose of 25 kg/ha. See Lahkim Bennani *et al*. (in this volume) for more information on climate and soil.

The plants were taken from each line at the vegetative (March 12, 2018), at the budding (March 26, 2018) and at the flowering stages (April 18, 2018). The aim was to measure: plant height, dry matter yield (DMY), leaves/steam ratio (LSR), the stem diameter (SD), number of stems and foliar area.

III – Results and discussion

The results obtained show that the origin of genotypes affects considerably the LSR ($P<0.001$). This ratio varies from 0.6 recorded for E1, E9 and E17 to 1.18 recorded for the E3 ecotype (Table 1). This last ecotype showed an important potential biomass's foliar production compared to the stem (approximately 20%). E3 ecotype stands significantly out from the rest of the collection by a thin diameter of stem (6.30 mm). Overall, it is shown that yellow sweet clover plant is characterized by a more massive stem compared to the leaf. Indeed, the majority of the ecotypes (80%) have a LSR which varies between 0.66 and 0.80 (Table 1). Luo *et al*., (2016) reported a superior LSR with 0.96 and a larger stem with 1.69cm.

In term of dry matter's yield, the totality of the ecotypes showed an important production potential varying from 4 to 14.81 DMY/ha ($P<0.05$). The highest DMY was recorded by E34, E2a, E22 and E21 with respectively 14.81; 13.50; 13.49 and 11.93 t/ha. These ecotypes showed more interesting results in terms of production's potentiality, but are characterized by an important LSR (0.70 on average) and a less thin stems (on average 7.05 mm). To keep the hay's production successful, the seedling dose should be studied to improve these parameters.

When the plants were at the vegetative stage, no significant difference concerning the height of the plant was noticed between the ecotypes. However, it is noted that at this early stage, 50% of the ecotypes reached a height exceeding 100 cm (Table 1). At the flowering stage, the plant reaches 142 cm height. Similar results were reported by Goplen *et al.,*(1984).

Table 1. Agronomic and morphological measurements of collection of yellow sweet clover ecotypes (average of stages ± standard error)

Ecotype	DMY (t/ha)	Plant height (cm)	LSR	Stem diameter (mm)	Stems (no.)	Foliar area (mm^2)
E1	6.14±0.26	93.98±10.13	0.60±0.03	6.44±0.35	15.22±4.49	21.92±4.45
E2a	13.50±1.29	104.28±12.89	0.68±0.04	7.08±0.58	20.33±4.53	24.41±5.09
E2	6.78±0.62	107.98±11.28	0.71±0.08	8.03±0.41	15.33±3.28	26.94±8.93
E3	4.00±0.17	80.47±9.12	1.18±0.09	6.30±0.39	14.78±4.87	21.14±2.77
E34	14.81±0.53	103.57±7.74	0.67±0.06	7.28±0.63	20.67±4.47	22.68±8.89
E9	5.14±0.21	93.85±7.81	0.60±0.05	6.21±0.34	15.56±1.81	22.71±5.37
E10	7.81±0.66	96.12±12.58	0.74±0.07	7.16±0.36	17.11±6.31	25.27±6.59
E11	5.71±0.42	105.55±14.47	0.73±0.06	7.37±0.39	16.67±3.94	28.20±6.64
E12	7.48±0.33	101.88±11.12	0.68±0.06	6.80±0.42	16.56±3.43	27.37±6.07
E13	4.10±0.73	92.68±13.58	0.69±0.06	6.27±0.49	15.63±4.14	22.93±6.07
E14	6.01±0.32	78.3±11.16	0.80±0.05	7.06±0.26	15.00±2.92	24.41±6.64
E15	5.84±0.53	104.25±10.89	0.66±0.03	6.69±0.34	15.56±3.24	24.93±7.11
E16	9.35±0.58	99.58±13.25	0.68±0.04	7.31±0.33	15.00±3.32	27.02±5.95
E17	10.30±0.54	104.69±12.94	0.60±0.02	6.38±0.27	16.75±4.03	23.99±5.38
E18	10.91±0.45	106.7±13.00	0.71±0.02	7.21±0.35	18.89±5.37	23.17±4.96
E19	7.34±0.59	96.98±12.72	0.75±0.05	7.06±0.33	17.11±3.66	21.98±4.36
E20	9.35±0.62	98.73±15.22	0.71±0.08	6.66±0.56	18.00±5.36	21.23±5.63
E21	11.93±0.76	112.25±14.81	0.67±0.03	7.11±0.46	19.00±4.90	24.82±4.97
E22	13.49±0.72	106.45±10.88	0.78±0.09	6.73±0.36	19.11±4.62	21.47±4.34
E23	10.58±0.46	98.85±13.05	0.68±0.06	8.91±0.33	18.00±3.39	24.52±5.73
Moy.	8.53±1.84	99.36±35.36	0.71±0.20	7±1.32	17.71±4.10	24.06±5.80
Pro.	0.0046	0.9581	<0.0001	0.0014	0.1929	0.3262
Sig.	*	**N.S**	***	**	**NS**	**NS**

The growth of the plant affects very significantly all the studied parameters. All of those parameters increase with the vegetative stage (Table 2). At the flowering stage, *Melilotus officinalis* reaches, on average, a production in biomass of 10.59 TDM/ha, a LSR fairly high and a thin stem (7.7 mm). This yield is higher than that obtained by Hadj Omar *et al*. (2018) for the alfalfa at the stage of flowering. These results make *M. officinalis* a good fodder plant. However, more work should be undertaken in order to improve these characteristics, in particular a finer stem and a higher foliar biomass.

Table 2. Agronomic and morphological measurements of yellow sweet clover by stage of growth

Stage	DMY (t/ha)	Plant height (cm)	LSR	Stem diameter (mm)	Stems (no.)	Foliar area (mm^2)
Vegetative	06.44±0.13	61.96±1.42	0.82±0.02	6.5±0.19	14.54±3.24	22.72±4.61
Budding	08.57±0.1	93.75±1.57	0.72±0.02	6.78±0.16	17.08±2.74	23.55±5.24
Flowering	10.59±0.23	142.36±1.77	0.61±0.02	7.74±0.1	21.50±3.68	25.89±7.46
Average	8.53±1.84	99.35±35.36	0.71±0.2	7±1.32	17.71±3.22	24.05±5.77
Pro.	<0.001	<0.001	<0.001	<0.001	<0.001	0.0104
Sign.	***	***	***	***	***	*

IV – Conclusions

According to these results, it is shown that the yellow sweet clover could be a plant with strong potential of fodder production with a maximum production of 14.81 DMY/ha. Among the studied collection, a group of 4 ecotypes (E34, E2a, E22 and E21) reached on average a very high yield (13.43 DMY/ha). The majority of the ecotypes carried out a variable yield between 6.01 and 10.91 DMY/ha. Considering its height varying between 0.6 and 1 m at the vegetative stage, and its foliar mass which is moderately high, it has a huge interest for animal feeding.

In spite of its poor yield, E3 ecotype stands out by an important foliar area and a moderate stem diameter. These specificities confer to this ecotype, the ability of being utilized for obtaining a good quality hay.

However, these observations need to be improved and the results should be considered as preliminary in view of extend the collection of data for 2-3 years.

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Nutritive value of *Melilotus officinalis* ecotypes from the North-western Moroccan pastures

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Abstract. Twenty ecotypes of *Melilotus officinalis* (L.) Pall. (yellow sweet clover) were collected from the North-western pastures of Morocco, and then cultivated in the experimental station of INRA in Tangier. The harvesting was realized during the vegetative, budding and flowering stages in order to study their nutritive value. The results indicate that nutritive value of *M. officinalis* depends significantly on the vegetative stage of sampling and the ecotype origin. From the vegetative to the flowering stage, the ash content decreases from 14.01 to 8.60% on dry matter (DM) ($P<0.001$), from 5.76 to 2.90% DM for ether extract or fat (FM), from 19.43 to 14.51% DM for crude protein (CP). However, the content of indigestible fibers increases significantly ($P<0.001$) from 3.50 to 6.65% DM for lignin (ADL). Otherwise, the content of nutritive value was very highly affected by the origin of ecotypes ($P<0.001$). They varied between 15.99% and 18.41%DM, 10.20% and 13.48% DM, 3.46% and 5.51% DM, 7.23% and 2.46% DM respectively for CP, ash, FM and ADL. Considering its adaptation to local environmental conditions of the north-west and its high nutritive value, the selected ecotypes of *M. officinalis* can contribute to improve the quality and quantity of proteins for animal breeding in the region.

Keywords. *Melilotus officinalis* – Moroccan ecotypes – Nutritive value – Pasture.

La valeur nutritive des écotypes de* Melilotus officinalis *des pâturages du nord-ouest marocain

Résumé. *Une sélection de vingt écotypes de* Mélilotus officinalis *a été collectée des pâturages du Nord-Ouest du Maroc, puis cultivée dans la station expérimentale de l'INRA de Boukhalef. L'échantillonnage a été réalisé au stade végétatif, bourgeonnement et à la floraison afin d'évaluer leur valeur nutritive. Les résultats obtenus indiquent que la composition chimique de mélilot dépend strictement du stade de fauche et présente une diversité très hautement significative en termes de teneur en protéines, matière grasse, minéraux et en fibres. En allant du stade végétatif à la floraison, la teneur en minéraux (MM) diminue très significativement en passant de 14,01%MS à 8,60%MS, de 5,76%MS à 2,90%MS pour la matière grasse (MG), de 19,43%MS à 14,51%MS pour les protéines (MAT). En revanche, la teneur en fibres indigestible (lignine) augmente très significativement de 3,50%MS à 6,65%MS. Pour les écotypes, la teneur en protéines (MAT) varie entre 18,41%MS et 15,99%MS, 13,48%MS et 10,20%MS pour MM, 5,51%MS et 3,46%MS pour MG et entre 7,23%MS et 2,46%MS pour ADL. Vu son adaptation à la région du nord et sa haute valeur nutritive, cette espèce peut contribuer à l'amélioration de la qualité et la quantité protéique de l'offre alimentaire des élevages de la région.*

Mots-clés. Melilotus officinalis – *Écotype – Valeur nutritive – Pâturage.*

I – Introduction

Given the dearness of livestock's feed prices and the increase of the feed amounts needed for goats breeding, the identification and the evaluation of the nutritive value of new pastoral fodder species, which can be incorporated in goats feed ration, has become an important task to face the animal feeding requirements.

Yellow sweet clover (*Melilotus officinalis* L.) is an indigenous species, which grows spontaneously in the natural pastures of the North-western areas of Morocco. This legume plant can reveal a significant agro-economic and nutritional interest considering its availability in the area and its important content of proteins, phosphorus and calcium (Urness *et al.*, 1975).

The aim of this study was to better know the nutritive value of a collection of yellow sweet clover ecotypes in order to evaluate its fodder value for its valorization in the goat's food.

II – Materials and methods

A collection of 20 ecotypes of *M. officinalis* from North Western Moroccan pastures were grown in the experimental field of Boukhalef (Tangier) on 13th November 2017. See Lahkim Bennani *et al*. (in this volume) for more information about the collection sites. Each ecotype was established on a plot of 10x2 m with 1m separation from each other. The plot was subdivided in 5 lines with a line space of 40 cm. Each line was sown with an amount of 10 g corresponding to a seed dose of 25 kg/ha. Approximately 2 kg of green matter was collected from each line in the vegetative (March12, 2018), budding (March 26, 2018) and flowering stage (April18, 2018) for each ecotype.

The experimental field of Boukhalef –Tangier– (35° 43' 49''N, 5° 25' 59''W) is located at an altitude of 30m. The climate is Mediterranean, with an average of temperature min and max of 2°C and 24°C, respectively. The total rainfall during the period of essay was 892 mm and humidity was between 76% and 81%. The soil is flat and heavy (black clay) with a very fine texture.

The samples of different ecotypes were dried at 60°C then grinded in 1 mm and analysed according to methods AOAC (1997). All the analysed components are reported on dry matter (DM) basis. The ash content was obtained according to method AOAC. The content of crude protein (CP) was evaluated according to the method of Kjeldhal. The fat content (FM) was extracted by using the method Soxhlet. The proportion of fibers (ADL) was carried out according to the sequential method of Goering and Van Soest (1975) with the fibre analyzer Ankom 200.

III – Results and discussion

Variability of the studied parameters is very highly significant within the collection of the yellow sweetclover (Table 1, P<0.001).

The melilot seems to be rich in ash with an average content of 11.08% DM; results were higher than those found by Canbolat *et al*., 2009. In fact, among the 20 studied ecotypes, E14, E23, E12, E17 and E11 recorded the most important contents (Table 1).

The CP content ranged from 15.99 % to 18.41 % DM. E23, E16, E34, E 11, E19, E18 ecotypes contain high CP content with 18% DM (Table 1). However, Canbolat *et al.* (2009) found a lower content, in order of 15.91%DM.

Concerning lignin's content, we note a significant difference between ecotypes but doesn't generally exceed 7.23% DM (Table 1). Yellow sweet clover is also described as a medium energy forage since the average content was 4.18% in FM and remains less than 5.5%. The majority of ecotypes was characterized by an FM rate ranging from 3.5% to 4.5%.

TAs shown in the Figure 1 below, all the studied parameters are affected very significantly with the advance of the stages (P<0.001).

The parameters Ash and, FM follow the same pattern with the advance of the stages. A respective reduction was noticed from 14.01; 5.76% recorded at the vegetative stage, to 8.60; 3.01% at the flowering stage.

Table 1. Chemical composition (%DM) of a collection *M. officinalis* ecotypes (average of stages ± stdrd)

Ecotype	Ash	FM	CP	ADL
E1	10.34^{hi}±0.41	4.47^{e}±0.61	17.79^{bcd}±0.30	6.36bc±0.51
E2a	10.34^{ghi}±0.95	3.48^{l}±0.25	16.09^{hi}±0.70	7.23^{a}±0.74
E2	10.40^{ghi}±0.61	4.59^{d}±0.54	16.42^{fgh}±0.74	6.08^{cd}±0.71
E3	10.82^{fghi}±0.63	4.10^{g}±0.55	17.55^{d}±0.64	5.57^{def}±0.57
E34	10.29^{hi}±0.42	4.13^{g}±0.35	18.08^{ab}±0.19	6.85^{ab}±0.21
E9	10.38^{ghi}±0.46	4.57^{d}±0.63	17.62^{cd}±0.77	5.37^{cde}±0.85
E10	10.20^{i}±0.64	4.31^{f}±0.43	17.69^{bcd}±1.05	6.39^{bc}±1.05
E11	11.60^{cde}±1.22	4.36^{f}±0.51	18.03^{abc}±1.30	4.99^{fg}±0.88
E12	11.99^{bc}±1.40	3.88^{h}±0.23	16.65^{efg}±0.78	5.17^{efg}±0.31
E13	11.16^{defg}±1.07	3.58^{j}±0.23	16.24^{ghi}±0.96	5.03^{i}±0.71
E14	13.48^{a}±1.12	3.48^{k}±0.21	16.34^{fghi}±0.68	4.82^{i}±0.44
E15	11.45^{cde}±0.76	3.76^{i}±0.14	16.71^{ef}±0.22	5.55^{def}±0.85
E16	11.24^{cdef}±0.69	4.30^{f}±0.26	18.24^{a}±0.91	2.46^{k}±0.37
E17	11.85^{bcd}±1.49	3.80^{i}±0.23	15.99^{i}±0.80	2.93^{jk}±0.29
E18	10.57^{fghi}±0.47	4.14^{g}±0.21	18.01^{abc}±0.81	4.95^{fg}±0.67
E19	11.36^{cdef}±0.71	5.51^{a}±0.97	18.02^{abc}±0.41	3.07^{jk}±0.39
E20	10.36^{ghi}±0.88	4.71^{c}±0.92	17.56^{d}±1.07	3.60^{ij}±0.15
E21	11.06^{defgh}±0.68	4.86^{b}±0.93	17.48^{d}±0.91	4.66^{gh}±0.34
E22	10.29^{hi}±0.64	3.46^{k}±0.03	16.79^{e}±1.16	4.06^{hi}±0.31
E23	12.47^{b}±1.16	4.30^{f}±0.31	18.41^{a}±1.26	2.82^{k}±0.33
Signif.	***	***	***	***

The CP reaches the maximum level at the vegetative stage with 19.43%. As for all the other parameters, the content of proteins decreases significantly while the plants grow. The low levels were obtained at the flowering stage with an average of 14.51%. Lignin increases gradually with the plant's growth but remains generally moderate (6.65%) (Fig. 1).

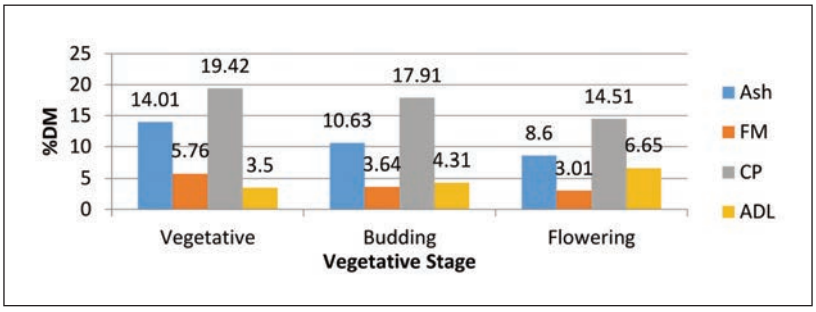

Fig. 1. Chemical composition (%DM) of *M. officinalis* with stage of plant growth.

The contents obtained from FM, CP and MM were largely higher than those found by Canbolat *et al*. (2009). They reported respective contents of 1.99%, 15.91% and 6.98%. The same authors found a higher content of lignin with 12.74%.

In comparison with other fodder plants which are characterized by their interesting nutritive value, the species *Trifolium repens* recorded at the flowering stage a lower contents of CP and FM with about 15.08%DM, 3.29%DM respectively (Kiraz., 2011). Boualil (1983) reported that the alfalfa is very rich in CP with an average content of 19.0% and little lignified with 6.3% for ADL.

Rohweder *et al.* (1978) set up a standard based on laboratory analyses for the evaluation of the forage's quality. This standard revealed that the quality of fodder having a content of CP higher than 19% proves to be excellent, content between 17 and 19% is classified like very good, the quality of fodder is regarded as good if the content of CP ranges between 14 and 16%.

All the ecotypes can be considered as a very good quality, except E17. Concerning the effect of the growth stage on the nutritive value, it decreased significantly, nevertheless, these ecotypes can be classified of excellent quality at the vegetative stage, very good at the budding stage and good quality at the flowering stage.

IV – Conclusions

The North Western Moroccan ecotypes of *M. officinalis* have a very significant diversity in terms of protein content, fat content, mineral content and fibers.

This study revealed that the nutritive value varies considerably according to the ecological origin of the ecotype and the growth stage. The vegetative stage followed by the budding stage were richer in nutrients, and thus are most suited to foddering. The ecotypes E23, E16, E34, E11, E19 and E18 showed the most interesting protein values, fat content, as well as a low content of ADL.

Considering its adaptation to the North-West of Morocco, its high forage production (Lahkim Bennani *et al.* in this volume) and its high feeding value, this species can contribute to improve quality and protein's amount of the animal diet. However, more studies are needed in order to develop the best sward management and it's fully valorization in the farming systems.

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The variability in qualitative determinants of Greek bitter vetch landraces

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Abstract. Bitter vetch (*Vicia ervilia* (L.) Willd.) is one of the eight Neolithic founder crops of the Fertile Crescent. Once extensively cultivated, nowadays is growing on a small scale around the Mediterranean Basin for its forage and grain, mainly as feed for ruminants. Efforts for conservation and quality determinants assessment have been intensified in the recent years, due to increased attention for underutilized crop species and their effect to global food security and the forthcoming climate change. Seed nutritional quality varied significantly (P<0.001), among forty-one Greek bitter vetch landraces. Ash content averaged at 2.66 g/100 g DM. Crude protein content ranged from 15.5 to 23.31 g/100 g DM and crude fiber from 2.79 to 4.05 g/100 g DM. NFEs also varied with an average of 62.03 g/100 g DM. Straw quality characteristics were also varied among six studied accessions. Crude protein and crude fiber contents ranged from 5.10 to 9.84 g/100 g DM and 32.06 to 43.06 g/100 g DM, respectively. ADF and NDF contents averaged at 39.02 g/100 g DM and 52.63 g/100 g DM, respectively. The seeds and straw of the Greek bitter vetch local populations studied revealed on average a nutritional value similar to that of collections studied elsewhere. However, local populations of interesting performance were identified which need further study.

Keywords. *Vicia ervilia* – Nutritional quality – Population diversity – Underutilized crop.

La variabilité dans les déterminants qualitatifs des races locales de vesces amères grecques

Résumé. *La vesce amère (*Vicia ervilia *(L.) Willd.) est l'une des huit cultures fondatrices néolithiques du Croissant fertile. Autrefois largement cultivée, elle est trouvée aujourd'hui à petite échelle autour du bassin méditerranéen, pour la production de fourrage et de grain, principalement pour nourrir les ruminants. Les efforts en matière d'évaluation de la conservation et des déterminants de la qualité se sont intensifiés ces dernières années en raison de l'attention accrue portée aux espèces cultivées sous-utilisées ainsi que de leurs effets sur la sécurité alimentaire mondiale et du changement climatique à venir. La qualité nutritionnelle des semences variait de manière significative (P<0,001) parmi quarante-et-une races locales grecques de vesces amères. La teneur en cendres était en moyenne de 2,66 g/ 100 g de MS. La teneur en protéines brutes variait de 15,5 à 23,31 g/ 100 g de MS et la fibre brute de 2,79 à 4,05 g/ 100 g de MS. Les NFEs ont également varié avec une moyenne de 62,03 g/ 100 g de MS. Les caractéristiques de qualité de la paille variaient également parmi six accessions étudiées. Les teneurs en protéines brutes et en fibres brutes variaient respectivement de 5,10 à 10,47 g/ 100 g de MS et de 32,06 à 43,07 g/ 100 g de MS. Les teneurs moyennes en ADF et en NDF étaient en moyenne de 39,02 g/ 100 g de MS et de 52,63 g/ 100 g de MS, respectivement. Les graines et la paille des populations locales de vesce amère grecque étudiées ont révélé en moyenne une valeur nutritionnelle semblable à celle des collections étudiées ailleurs. Cependant, des populations locales présentant des performances intéressantes ont été identifiées et nécessitent une étude plus approfondie.*

Mots-clés. Vicia ervilia – *Qualité nutritionnelle – Diversité de la population – Culture sous-utilisée.*

I – Introduction

Sheep and goats constitute a vital source of income for the rural population of many Mediterranean areas, contributing greatly to family and also to national economies through their products (meat, milk, skins wool, etc.), while they provide a range of ecosystem services. Although the main source of feed for these animals is the forage grazed on extensive rangelands, cereal straw and stubble, as well as grains cropped locally (Porqueddu *et al*., 2017), the climatic conditions prevailing there, and the poor soils lead to feed scarcity and finally to low productivity. This situation can be reversed by selecting crops adapted to drought and by improving soil condition and fertility mainly through forage legumes cultivation, integrating them into the mixed crop-livestock or agro-pastoral farming systems as multi-purpose crops to improve seasonal supply of quality feed and soil productivity (Baxevanos *et al*., 2017).

Towards this goal, and in view of global warming, bitter vetch (*Vicia ervilia* (L.) Willd.) presents an interesting option. Bitter vetch is one of the eight Neolithic founder crops of the Fertile Crescent. Once extensively cultivated, nowadays is growing on a small scale around the Mediterranean Basin due to low productivity and contents of antinutritional components. However, conservation and quality assessment efforts have been intensified in the recent years, due to increased interest towards global food security and the forthcoming climate change. Therefore, this study aimed to assess seed and straw nutritional quality of a collection of bitter vetch accessions with Greek origin.

II – Materials and methods

1. Samples for seed quality determination

Seed samples of thirty-two bitter vetch accessions with Greek origin, kindly provided by the Genebank of Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) (*coded* ERV), in Germany, as well as nine landraces from different parts of Greece (*coded* AUA), collected on-farm, during expeditions of the laboratory of Plant Breeding and Biometry of Agricultural University of Athens were assessed regarding their seed qualitative determinants. For the analysis, two replications of fifty seeds each, were used per accession.

2. Samples for straw quality determination

Six of the accessions were further analyzed for their straw qualitative determinants. For that purpose, a field experiment was carried out in the Agricultural University of Athens (N 37º59'10'', E 23º42'29'', altitude 24 m). A Randomized Complete Block Design (RCBD) was followed with 4 blocks, each plot containing a total number of 40 plants. For the analysis, straw of ten central completely mature plants of each replication was used.

3. Analytical methods

Straw quality was assessed after it was pre-ground on a hammer mill to pass a 6 mm sieve. Seeds and the ground straw were finished on a laboratory mill using a 1 mm screen. Analyses were conducted for moisture (AOAC method 930.15), crude protein concentration (CP) by the Kjeldahl method (AOAC method 984.13), ash content (Ash) by ashing overnight at 550º C (AOAC method 942.05), ether extracts (EE) as Fat by the Soxhlet method (AOAC method 920.39), crude fiber (CF), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) on an ANKOM 220 (AOAC 978.10, AOAC 2002:04 and AOAC 973.18 respectively). Moreover, Nitrogen Free Extracts (NFE) were determined by difference using the equation NFE= 100– (CP + Ash+ CF + EE).

4. Statistical analysis

All data were subjected to a one-way Analysis of Variance (ANOVA) and Least Significant Difference (LSD) at 0.05 level was applied to define significantly different means among the accessions. Pearson correlation coefficients were computed to assess correlations among seed as well as straw nutritional traits studied, using Statgraphics Centurion 16 statistical package.

III – Results and discussion

Seed nutritional quality varied significantly (P<0.001), among forty-one bitter vetch landraces which were collected either from on farm cultivation in Greek rural areas or preserved *ex-situ* with Greek origin. Ash content ranged from 2.21 (ERV28) to 3.26 (ERV16) and averaged at 2.66 g/100 g DM. Crude protein content ranged from 15.5 (AUA5) to 23.31 (AUA9) g/100 g DM. Crude fiber from 2.79 to 4.05 g/100 g DM in ERV27 and ERV65, respectively. NFEs also varied from 57.98 (AUA3) to 65.01 (AUA5), with an average of 62.03 g/100 g DM (data not shown).

Straw quality characteristics were also varied among six studied accessions. Crude protein and crude fiber contents ranged from 5.10 to 9.84 g/100 g DM and 32.06 to 43.06 g/100 g DM, respectively. ADF and NDF contents averaged at 39.02 g/100 g DM and 52.63 g/100 g DM, respectively (Table 1). Greek accessions seed and straw nutritional value found to be similar to other bitter vetch collections (Hadjipanayiotou *et al*., 1985; Makkar *et al*., 1996; Tabatabaei *et al*., 2000; Sadeghi *et al*., 2009; Larbi *et al.*, 2011; Okba *et al*., 2014).

Table 1. Variability of straw chemical composition among 6 bitter vetch accessions (g/ 100 g of DM)

Accession	CP	Ash	CF	NDF	ADF	NFEs
AUA2	6.33±0.64^{cd}	11.74±1.40	36.21±1.88^{b}	50.49±2.62	38.49±2.39	38.66±0.99^{b}
AUA5	9.44±0.82^{ab}	9.69±0.24	36.57±2.71^{ab}	51.06±4.15	37.99±3.62	36.39±1.63^{b}
ERV35	5.10±0.47^{d}	10.43±0.42	32.23±0.44^{b}	49.14±1.39	35.19±1.09	52.90±7.77^{a}
ERV45	5.77±0.42^{cd}	8.78±0.90	37.90±1.98^{ab}	57.08±2.34	42.32±1.78	40.60±0.75^{b}
ERV53	9.84±1.00^{a}	10.81±0.72	32.06±0.01^{b}	51.93±2.86	37.50±2.47	41.14±0.01^{ab}
ERV65	7.51±0.96^{bc}	9.51±1.08	43.06±2.03^{a}	57.22±6.96	43.84±5.51	32.98±1.16^{b}
Mean	7.33	10.13	36.88	52.63	39.02	40.71
Significance	***	ns	*	ns	ns	*

Values are given as mean ± SE of four replicates. Means in columns with different letters are significantly different at P<0.05 by Least Significant Difference. ns. Non-significant at 0.05, *. Significant at the 0.05 level, **. Significant at the 0.01 level, ***. Significant at the 0.001 level.

In seeds, a strong positive correlation was defined only between fat content with NFEs (r=0.66, P<0.05), while negative correlation was observed between CP with NFEs content (r=-0.84, P<0.05) and with fat content (r=-0.85, P<0.05) (Table 2) indicating difficulties in breeding both for high CP content and high general nutritional value.

Table 2. Correlations among seed nutrient traits studied (P<0.05)

	DM	Ash	Fat	CF	CP	NFEs
DM	1.00	-0.46	-0.12	0.01	0.07	0.44
Ash		1.00	-0.17	-0.01	0.16	-0.49
Fat			1.00	0.48	-0.85	0.66
CF				1.00	-0.44	0.25
CP					1.00	-0.84
NFEs						1.00

Regarding straw nutritional traits studied, a strong positive correlation was observed between NDF and ADF content (r=0.98, P<0.05) as well as between CF with NDF and ADF (r=0.81, P<0.05 and r=0.88, P<0.05, respectively). High negative correlations were defined between CF and NFEs (r=-0.69 P<0.05) and ash content with NDF (r=-0.65 P<0.05) (Table 3). Therefore, our results indicate that, since ADF values have a proven negative correlation with ruminant digestion (Van Soest, 1991) and lower values of ADF are preferable for the animal production, a selection for a lower ADF, NDF and total CF straw content, like in accessions ERV35 and ERV53 is possible due to their strong positive correlations. Moreover, a selection for low CF content could lead to an increased NFE content (r=-0.69, P<0.05), however the correlations among other nutritive value traits were moderate or weak.

Table 3. Correlations among straw nutrient traits studied (P<0.05)

	DM	CP	Ash	CF	NDF	ADF	NFEs
DM	1.00	-0.32	-0.23	0.66	0.63	0.65	-0.17
CP		1.00	0.28	-0.21	-0.41	-0.39	-0.38
Ash			1.00	-0.53	-0.65	-0.58	0.11
CF				1.00	0.81	0.88	-0.69
NDF					1.00	0.98	-0.33
ADF						1.00	-0.40
NFEs							1.00

IV – Conclusions

The seeds and straw of the Greek bitter vetch local populations studied revealed on average a nutritional value, similar to that of collections studied elsewhere. However, local populations of interesting performance that were identified need further study regarding the appropriate feeding regimes and the necessary processing techniques in order to be implemented in animal feeding diets. Moreover, selection for preferable nutritional traits of bitter vetch, like CP in seeds, low CF in parallel to high NFE content in straw, could be feasible.

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Study of the cladodes phenotypic diversity of 36 accessions of cactus in the arid region of Tafilalet

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Abstract. The prickly pear (*Opuntia ficus indica* Mill.) could be one of the most important forage crop species in the arid southeast region of Morocco. In this work, we report the analysis of cladodes traits belonging to 36 accessions of prickly pear (28 accessions of *Opuntia ficus indica* form inermis and 8 accessions of *Opuntia ficus indica* form amycleae) from different regions of Morocco and grown in the experimental station of Errachidia. Twenty-three phenotypic characters of cladodes were analyzed using analysis of variance and multivariate analysis (PCA). All attributes were significantly different within and between the two forms of cacti. The shape of the cactus and the geographical origin affected the characteristics of the cladodes. Comparison of our results with those obtained for the same accessions grown in the station Melk Zehar located in Agadir (southwest Morocco) revealed significant differences in favor of the Agadir environment. This study allowed us to group the characters of the cladodes into three classes for the two cactus forms.

Keywords. Opuntia – Cladodes – Phenotypic variability – Accessions.

Étude de la diversité phénotypique des cladodes de 36 accessions de cactus dans la région aride de Tafilalet

***Résumé**. Le figuier de Barbarie (*Opuntia ficus indica *Mill.) pourrait être l'une des espèces fourragères alternatives importantes du point de vue agro-économique dans la région aride du sud-est du Maroc. Dans ce travail, nous rapportons l'analyse des raquettes de 36 accessions de figuier de Barbarie (28 accessions d'*Opuntia ficus *indica forme inermis et 8 accessions d'*Opuntia ficus *indica forme amycleae) provenant de différentes régions du Maroc et cultivées dans le domaine expérimental d'Errachidia. Vingt-trois caractères phénotypiques de la raquette ont été analysés en utilisant l'analyse de la variance et l'analyse multivarié (ACP). Tous les paramètres se sont révélés significativement différents au sein et entre les deux formes de cactus. La forme du cactus et l'origine géographique ont affecté les caractéristiques de la raquette. La comparaison de nos résultats avec ceux obtenus pour les mêmes accessions d'Opuntia cultivées dans le domaine de Melk Zehar d'Agadir (sud-ouest Morocco) ont révélé des différences notables en faveur de l'environnement d'Agadir. Cette étude nous a permis de grouper les caractères de la raquette en trois classes et ce pour les deux fromes de cactus.*

***Mots-clés.** Cactus – Raquette – Variabilité phénotypique – Accessions.*

I – Introduction

Cactus species are native to the Americas. *Opuntia ficus indica* Mill. is mainly grown in dry, arid and semi-arid countries, including Morocco, Tunisia, Algeria, South Africa, Italy, Brazil, Argentina, Chile and Mexico (Felker and Inglese 2003). The Cactus was introduced in Morocco around the 16th century. Its area has constantly increased from 50,000 ha in 1998 to more than 140,000 ha (Arba *et al*., 2000; 2009).

Several successful genotype breeding programs are carried out around the world, including Mexico, United States, Italy, India, South Africa and Argentina (Reyes-Aguero *et al*., 2005; Zoghlami *et al*., 2007; Peña-Valdivia ert al. 2008; De Wit *et al*., 2010; Soni *et al.,* 2015; Nefzaoui, 2016; Samah *et al*., 2016; Adli *et al*., 2017; Mondragón-Jacobo and Chessa, 2017) .

Moroccan national genetic diversity of this species is apparent with different color varieties and harvest periods that vary from one variety to another and from one locality to another. The main varieties distinguished by the farmers are: Aissa, Moussa, Dellahia, Al Akria, Achter, Draibina, Acherfie and Mles. In addition, most of the published information on the biodiversity of cacti grown in Morocco focuses on these varieties (Boujghagh, 2011 ; El Finti *et al*., 2013 ; Bendhifi *et al*., 2015 ; El Kharrassi *et al*., 2016 ; Mabrouk *et al*., 2016).

Therefore, given the important role of the genus *Opuntia* in the ecology of arid and semi-arid regions of Morocco and its valuable diversity, we conducted this experiment that consisted in evaluating the morphological characteristics of the cladodes of 36 accessions of *Opuntia* and identifying the main features that contribute to their discrimination.

II – Materials and methods

The field trial was conducted at the Errachidia experimental station (31°55 N; 4°26.9; 1060 m a.s.l.). It was planted during March 2011. The soil of the test plot is sandy-loamy. The average annual rainfall is 139 mm and summer temperatures can reach 50ºC. The winter is very cold and the minimum temperature can drop to –7°C (29-years data from the Errachidia experimental station).

The plant material studied was the genus *Opuntia* sp. which includes two species: *Opuntia ficus indica* Mill form inermis and *Opuntia ficus indica* Mill form amycleae (syn: *Opuntia Megacantha* Slam Dyk). Thirty three cladodes used in this study came from the Melk Zhar experimental station of Agadir. These accessions were collected from different regions of Morocco (Table 1). The other three accessions came from the Errachidia region. These accessions are quite representative of the diversity of the prickly pear in Morocco. Irrigation was provided by drip irrigation, according to the season of year and rainfall (generally six irrigations per year were ensured). Each ecotype was repeated 4 times. The density was 1250 plants / ha (2 x4 m). The experiment aimed to compare cladodes characters of 36 cactus accessions. The experimental design was a Complete Random Block design with 4 replications. The experimental unit consisted of a single shrub per accession.

Twenty-two quantitative morphological characteristics of cladodes were evaluated in this study (Table 2).The identification of suitable characters is an essential element for the selection of species, accessions, genotypes and / or cultivars. For this work we used the list of cactus descriptors previously developed by the International Technical Cooperation Network on Cactus and approved by Biodiversity International (Chessa and Nieddu, 1997). The evaluation was also performed in accordance with some *Opuntia* descriptors previously used by Reyes-Aguero *et al*. (2005). The characteristics studied were also recorded according to the test guidelines for cactus and xoconostle of the International Union for the Protection of New Varieties of Plants (UPOV, 2004).

For each accession, six healthy, with no malformations and non-lignified cladodes of two or three years old per accession were selected. These cladodes were harvested during the month of March. All the morphometric parameters were measured by a graduated scale. The thickness of the cladode, the length of the spines were measured with digital calipers. The surface and the perimeter were calculated by assimilating the cladode to an ellipse. The dry weight of cladode was obtained at 65°C in the oven during three days. The number of areoles per cladode was measured on a surface of 25 cm² on the central part of both sides of the cladode. The other attributes were quantified .The qualitative characteristics have been described and noted.

Table 1. Code and origin of the different accessions of cactus collected in Morrocco

Code	Collection site	Altitude (m)	Code	Collection site	Altitude (m)	Code	Collection site	Altitude (m)
18	Maader Tiznit	252	135	Aït Ayache (Khenifera)	1550	183	El-Jadida 2	20
29	Aït Boufouln S. Ifni	1040	137	Laassri (Khenifera)	520	T1	Er-Rachidia 1	1048
33	Tlata Isboya Sidi Ifni 1	305	141	Tighboula (Ksiba)	715	T2	Er-Rachidia 2	1042
36	Tlata Isboya S. Ifni 2	305	142	Kesbat Tadla	500	T3	Er-Rachidia 3	1055
70	Aghroud Agadir	10	145	Ouaouizeght (Beni Mellal)	900	45	Ouled Berhil Taroudant	490
77	Sebt Guerdane Taroudant	185	147	Ouled Ayach (Beni Mellal)	275	62	Taroudannt	238
83	Aït laaza Taroudant	275	149	Ouled Cheikh	750	93	Cherarda Oulad Taïma 1	128
105	Had Dra Essaouira	200	160	Ain Lahcen Titouan 2	240	96	Cherarda O. Taïma 2	128
114	Barraket Lamine Safi	147	161	Ain Lahcen Titouan 3	270	118	Jamaat Shaïm Safi	167
130	Assaka Ouarzazate	1380	174	Ouled Moussa (Bouznika)	365	131	Taliouine Taroudant	1200
132	Skoura Ouarzazate	1220	181	Azemour	28	157	Ain Lahcen Titouan 1	210
134	Rich (Midelt)	1320	182	El-Jadida 1	20	184	Sidi Ismail (El-Jadida)	150

Table 2. Attributes evaluated for the cladodes (Cladode descriptors)

CHR (AB) : Cladode height (cm)	D : Distance CE	NLAR : Number of lines of areolas
CD (CD) : Cladode diameter (cm)	CTH : Cladode thickness (cm)	NLARt : Number of lateral areoles
LDC : Lower diameter of the cladode (cm)	LLS : Length of the largest spine	FWC : Fresh weight of the cladode (g)
SI : Shape index AB/CD	LSS : Length of the smallest spine	DMC : Dry matter of the cladode (g)
UW (AE) : Upper width (cm)	NTH : Number of thorns	SC: Surface of the cladode (cm²)
LW (BE) : Lower width (cm)	DAR-D : Density of areoles on 25cm²	PC: Perimeter of the cladode (cm)
TWD : Top widest distance (cm)	NAR : Number of areoles in the center	
WDB : Widest distance in the bottom (cm)	TNAR/GI : Total number of areolas / cladode	

For quantitative traits, means ± standard deviation and coefficients of variation were calculated. The attributes measured were first subjected to variance analysis and the means compared with the Student Newman and Keuls (TSK) test at the 5% error threshold based on the smallest significant amplitude. Principal Component Analysis (PCA) was used to assess the degree of similarity between the tested attributes of Opuntia and to understand the relationships between them. We used the Xlstat 2014 software for statistical analysis.

III – Results and discussion

1. Analysis of the variability of the cladode shape

The analysis of the variance showed that all the measured parameters were significant according to the Student Newman and Keuls (TSK) test.

2. Comparison of cladode parameters between the Agadir and Errachidia stations

The cactus develops slightly different characteristics depending on the environment. Indeed, fourteen accessions of the 31 grown in the Errachidia station have developed a cladode mean lenght

bigger than that of those grown in Agadir station. Likewise for the maximum width, but for only 12 accessions that have developed a larger average diameter. The shape index is relatively similar between the two stations. In the same way, half of the accessions at Errachidia have developed a greater thickness compared to those of Agadir station. We should note that the thickness depends on the irrigation and the period of measurements. Nevertheless, there is a big difference in the number of spines and the length of the largest spine between the Agadir and Errachidia stations. The presence or absence of thorns is controversial. Indeed, accessions without thorns and growing in a stressful environment (heat, drought) could become spiny. Rebman and Pinkava (2001) reported that, in growing habitat, the presence of spines, the number of spines per areola, and the number of areolas may differ drastically between regions.

3. PCA Analysis of the main morphometric parameters of the cladode

The analysis of cladode characters by the scatter plot representation (Fig.1) of the PCA indicates variability and similarity between several accessions in this study. This variation in cladode characteristics certainly influenced the growth and the performance of the accessions.

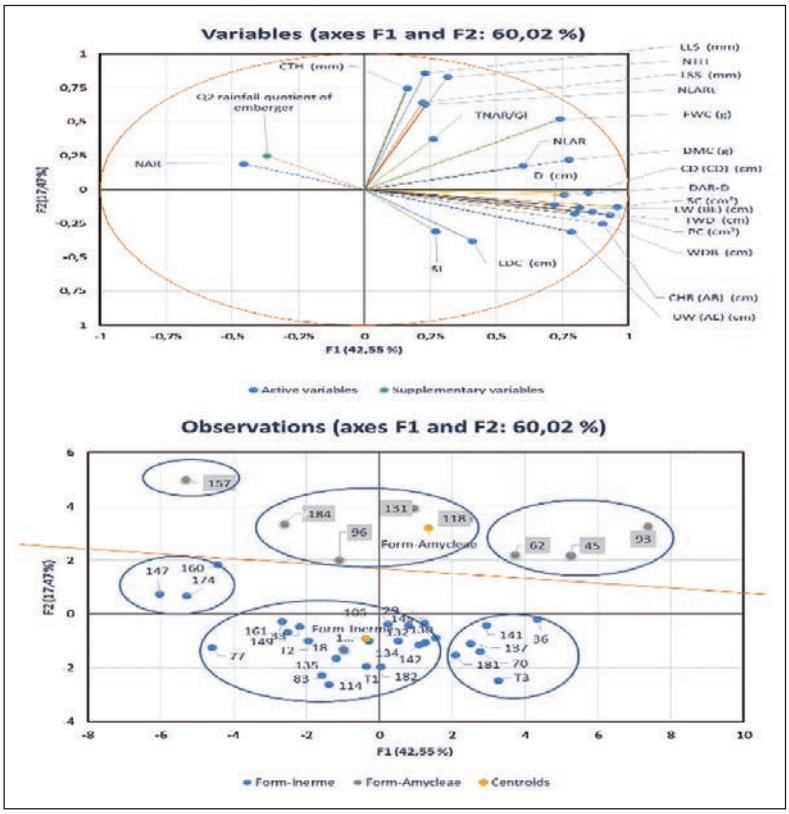

Fig. 1. Correlation circle (left side) and PCA analysis of cladodes parameters.

The first 3 components represent 70.98% of the variation. The first component represent 42.55% of variation and is defined by : CHR (AB), CD (CD), UW (AE), LW (BE), TWD, WDB, D, NAR, NLAR, FWC, DMC, SC and PC. The second component explains 17.5% of the total variation and is correlated to: CTH, LLS, LSS, NTH, NLARt and the shape of the cactus. The Third component (11%)

explain meanly the Shape index (SI). This result is satisfactory compared to Peña-Valdivia *et al* (2008) who reported that the first three CPs explained 46% of the total variability.

The biplot (1-2) showed the existence of different groups of accessions from the two forms (inermis and amycleae) (figure 1). The difference found between the inermis accessions and the amycleae ones would be due to the characters of the spines of the amycleae that are correlated with axis 2 (above the orange line). The same results were found by Colunga *et al*. (1986) who separated inermis and amycleae accessions from a group of 55 Opuntias including cultivated and spontaneous cultivars. Similarly, Peña-Valdivia *et al*., (2008) showed that the 46 Opuntia accessions from Mexico were separated into two groups according to the presence or absence of spines on the cladodes. In our case, the accessions on the right have the largest size, while those on the left are smaller and have important number of areola. Therefore, three groups can be distinguished in both forms. It seems that morphological characters are negatively correlated with Emberger's quotient Q2, which means that provenances with high Q2 will have smaller cladodes and vice versa. In this graph (Fig. 1) some parameters like Shape index (SI) are not explained (explained in the third component). Some characters are useless (not explained by the tree first component) in this study and further investigations should be done to reduce the number of descriptors.

IV – Conclusion

This evaluation of the cladode phenotypic diversity of prickly pear is important for establishing future breeding programs and for the *in situ* conservation of this germoplasm. Three classes or groups of cultivars of cactus have been observed among the two forms of cactus (six in total). These groups of prickly pear accessions have different characteristics (meanly size and thorns) represent a heritage of great importance. This paper explains only the variability of cladode shape, other reports will be focused on the fruit characteristics and the production.

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Morphological and agronomical evaluation of some Moroccan ecotypes of *Bituminaria bituminosa* (Tedera)

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Abstract. Forage pastures and legumes have been widely collected in the past, evaluated and valorised as varieties by many breeders worldwide. Some species where however under investigated, in spite of their potential use in animal feed. Perennial legumes as *Bituminaria bituminosa* is among the species which require special interest, considering their good forage quality and their ability to tolerate drought. Ten ecotypes of *Bituminaria bituuminosa*, collected from different areas of Morocco mainly Middle Atlas, High Atlas and the Rif, were evaluated for two years under field conditions for the following morphological and agronomical traits: flowering date, plant height (cm), leaf number, stem number, seed length and width, head number, flower number/head, leaflet with (cm), leaflet length (cm), color of flowers, branch number, mean stem diameter (mm), thousand seed weight (g), dry matter yield (g/plant) and grain yield (g/plant). An interesting genetic variability among studied ecotypes was found. In fact, the differences for all measured traits was highly significant (P<0.001) among ecotypes. In terms of dry matter production potential, some ecotypes were very promising. Further investigation should be made to include more ecotypes from other regions of the country.

Keywords. *Bituminaria bituminosa* – Moroccan ecotypes – Evaluation – Genetic variability.

Evaluation agro-morphologique d'une collection marocaine de* Bituminaria bituminosa *(Tedara)

Résumé. *Les espèces fourragères et pastorales ont été largement collectées dans le passé et exploité par les améliorateurs de différents pays. Plusieurs écotypes ont été utilisés pour produire des variétés commerciales. Toutefois, Certaines espèces n'ont pas été suffisamment valorisé ont malgré leur utilisation potentielle dans l'alimentation animale. Les légumineuses pérennes telles que Bituminaria Bituminosa nécessitent un intérêt particulier, compte tenu de sa qualité fourragère et de sa capacité à tolérer la sécheresse. Dix écotypes de Bituminaria collectés dans différentes régions du Maroc ont été évalués pour deux années au champ. Les paramètres mesurés sont la date floraison à 50% d'épiaison, hauteur des plantes à l'épiaison, rendement en matière sèche, rendement en grain, poids de 1000 graines, nombre de tiges, nombre des feuilles, nombre des inflorescences, nombre de fleur/inflorescence, longueur et largeur de la feuille médiane, diamètre de la tige principale et la longueur et largeur de la graine. Une variabilité intéressante a été trouvée parmi les écotypes étudiés. En effet, lL'analyse de la variance a révélé un effet très hautement significatif des écotypes pour les paramètres étudiés (P<0.001). En terme de production en matière sèche, certains écotypes se sont montrés prometteurs. D'autres collectes devraient être effectuées afin de couvrir les régions qui n'ont pas encore étaient prospectées pour inclure d'autres écotypes.*

Mots-clés. Bituminaria bituminosa – *Écotypes marocains – Évaluation – Variabilité génétique.*

I – Introduction

Due to climate change and their impacts, in particular the predicted increase in seasonal variability, we need new genotype and plant which are tolerant to summer drought and increase pasture yield and quality. *Bituminaria bituminosa* L. (Tedera) is a good model of resilient perennial legume. It is a promising fodder plant that may provide a source of quality feed for livestock over summer and autumn.

Tedera is native to the Island of Lanzarote, which belongs to the Canaries archipelago in the Eastern North Atlantic, 100 km of the coast of Morocco. A large diversity exists in the Canary Islands with 3 botanical varieties (Var. *Albomarginata*, var. *Crassiuscula* and var. *Bituminosa*). The fourth variety var. *hulensis* is present in Israel (Real *et al.*, 2009). Recently a new variety (var. *Antiatlantica*) which is endemic to Anti-Atlas Mountains (Morocco) was found. B. *antiatlantica* is a rare and localized species, currently known only from Mount Tachilla and Djebel Imzi in Southern Morocco (Brullo *et al.,* 2017). It is known under several common names such as “bitumen trefoil” (because of the strong smell of bitumen when the leaves are crushed) or “tedera” in the Iberian Peninsula (Munôz *et al*., 2000).

In Canary Island, tedera is traditionally used for feeding goats and sheep after cutting and drying, it is a valuable source of summer-green feed and assumed to be tolerant to heavy grazing (Foster, 2015; Sternberg *et al.,* 2006). Its nitrogen fixation and drought tolerance properties making it suitable for low-input production systems.

Tedera is extreme drought tolerance and remains green in summer and autumn in Mediterranean-type climates with minimal loss of leaves (Hamilton, 1974., Fedorenko *et al.,* 2009., Foster *et al.,* 2013). However there are a few studies of this species in Morocco. In the present study, some morphological and agronomical features of 10 ecotypes of *Bituminaria bituminosa* collected from different regions of Morocco were investigated.

II – Material and methods

Ten ecotypes of *Bituminaria bituminosa* were collected from different area of Morocco mainly North of Morocco, middle Atlas. Seeds of collected material were pre-germinated in petri dishes and trasplanted six weeks after in the field. Each ecotype was sown in a 1-m row of four plants and replicated twice. Row spacing was 0.2 m. The experience was carried out during 2017-2018 at the experimental field of El Koudia (Rabat; Morocco) under semiarid type climate on a loamy soil. The total rainfall was 624.5 mm.

The measured variables were flowering date at 50% of heading**,** plant height (cm), leaves number, stem number, seed length and width, heads number, flower number/head, leaflet with (cm), leaflet length (cm), color of flowers, branch number, mean branch diameter (mm) using a vernier caliper, 1,000 seed weight (g), dry matter yield (g/plant) and grain yield (g/plant).

For dry matter yield (g/plant), samples were collected in March 2018 from 3 plants per ecotypes. Plant sample were oven dried at 60°C until a constant weight was achieved. Seeds were collected weekly at maturity. The 1,000 seed weight was calculated from the average weight of 4 replicated subsamples of 100 seeds for each accession.

The data were analyzed using Genstat v18 software.

III – Results and discussion

The values of morphological and agronomical traits of *Bituminaria* are given in Table 1. An important genetic variability was observed for Moroccan ecotypes of Tedera. In fact, the differences for all measured traits was highly significant (P<0.001) among ecotypes.

Table 1. Averages, standard errors and coefficients of variation of morphological and agronomic traits of 10 *Bituminaria* ecotypes

Morphological and agronomical traits	Mean	SE	CV
Flowering date (day from 1st January)	147	± 1.3	1.1
Plant height (cm)	58.8	± 3.7	7.5
Leaves number	136.1	± 13.13	11.8
Stem number	19.3	± 2.4	22.2
Seed length (cm)	1.38	± 0.07	6.1
Seed width (cm)	0.29	± 0.02	8.1
Heads number per plant	77.8	± 8.2	17.4
Flower number/head	17.37	± 3.9	27.5
Dry matter yield 1st year (g/plant)	94.5	± 3.46	12.3
Dry matter yield 2sd year (g/plant)	361.7	± 27.8	9.4
Grain yield (g/plant)	21.7	± 1.3	7.5
Leaflet width (cm)	2.83	± 0.26	11.4
Leaflet length (cm)	6.01	± 0.37	7.6
Mean branch diameter (mm)	6.91	± 1.3	23.4
1,000 seed weight (g)	23.85	± 0.5	2.8

According to the results, average plant height was 58.5 cm and it ranged from 43 cm to 71 cm. Flowering date varied between 131 to 164 days. Number of flowers per head varied from 9 to 24 flowers and varied also within the same ecotype. Average number of leaves per head was 136, ranging from 64 to 190. It ranged between 64 and 190. It was noted that leaves remained green till seed maturation, without any irrigation in summer, which is one of the most specific character of Bituminaria. Tedera is one of the rare species which can stay green in summer and offer plentiful roughage high in quality. Average seed length and width was 1.38 cm and 0.29 cm respectively. Seed length varied from 1.1 cm to 1.9 cm while, seed width was between 0.28 cm and 0.32 cm. The thousand seed weight varied from 18 g to 28 g. Dry matter yield per plant for the first and the second year was in average 95 g/plant and 362 g/plant respectively. Grain yield showed a big variation and ranged between 7 g/plant and 35 g/plant.

IV – Conclusion

An interesting variability among studied ecotypes was found. These results open the way to test these ecotypes and evaluate their production under normal sward densities.

These preliminary results are very encouraging in view of the valorisation of *Bituminaria* as perennial forage legume for marginal rainfed areas.

Bituminaria is mostly evaluated for grazing. Animals prefer graze its leaves and fresh sprouts, so chemical prosperities of leaves and stems must be analyzed.

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Yield and chemical composition of Morrocan chickpea (*Cicer arietinum* L.) genotypes crop residues

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Abstract. Food legumes crop residues are a valuable forage resource in low rainfall areas with a high integration of crops to livestock. Since 1987, eighteen varieties of chickpea are recorded based on their grain yield, tolerance to drought and diseases in the Moroccan official catalog. However, till now there is a lack of studies targeting the food legume crop residues yield and quality. Thus, the aim of this study is to evaluate the yield and the chemical composition of eight Morrocan chickpea genotype residues. Four varieties (Farihane, Arifi, Zahour, Douyet) and four advanced genotypes (Flip85-1C, Flip97-190C, Flip97/114C, Flip97-677C) were arranged in randomized complete block design with four replications in 2016 at Jmaat Shaim experimental station. The harvested residues were dissected into stem segments and leaves. The Flip97-677C showed the highest crop residue yield 3.63 t/ha. The leaves proportion ranged from 44% for Flip85-1C to 49% for Flip97-190C. The crude protein (CP) content ranged from 63 to 89 g/kg DM, with Flip97-677C showing the highest CP. Neutral detergent fiber, acid detergent fiber and acid detergent lignin contents ranged from 568 to 661, 378 to 435 and 99 to 108 g/kg DM respectively. The average value of ash was 885 g/kg DM. The leaves had higher protein and ash contents and lower levels in different fiber parameters than stems for all genotypes.

Keywords. Chickpea genotypes – Crop residues – Yield – Morphological fractions – Chemical composition.

***Rendement et composition chimique des fanes de quelques génotypes marocains de pois chiche* (Cicer arietinum L.)**

Résumé. *Dix-huit variétés de pois chiches ont été répertoriées sur la base de leur rendement en grains, de leur tolérance à la sécheresse et aux maladies dans le catalogue officiel marocain depuis 1987. Cependant, peu d'études ont été consacrées au rendement et à la qualité de leurs fanes. L'objectif de cette étude est d'évaluer le rendement et la composition chimique des fanes de pois chiche de huit génotypes: quatre variétés (Farihane, Arifi, Zahour, Douyet) et quatre lignées prometteuses (Flip85-1C, Flip97-190C, Flip97 / 114C, Flip97-677C). Les génotypes ont été disposés en blocs aléatoires complets avec quatre répétitions en 2016 à la station expérimentale Jmaat Shim. Les fanes récoltées ont été disséquées en segments de tiges et de feuilles. Le Flip97-677C a montré le rendement le plus élevé en fanes soit 3,63 t/ha. La proportion de feuilles dans les fanes a varié de 44% pour Flip85-1C à 49% pour Flip97-190C. La teneur en protéines brutes (PB) a oscillé entre de 63 à 89 g/kg MS. Le Flip97-677C avait la teneur la plus élevée en PB. Les teneurs en fibres détergentes neutres, en fibres détergentes acides et en lignine détergente acide ont varié de 568 à 661, 378 à 435 et de 99 à 108 g/kg MS, respectivement. La valeur moyenne des cendres a été de 885 g/kg MS. Les feuilles ont des teneurs en protéines et en cendres plus élevées et des teneurs en différents paramètres de fibres plus faibles que les tiges pour tous les génotypes. Les fanes de légumineuses alimentaires constituent une ressource fourragère précieuse dans les zones à faible pluviométrie où l'élevage est fortement lié aux cultures*

Mots-clés. *Variétés pois chiche – Fanes – Rendement – Fractions morphologiques – Composition chimique.*

I – Introduction

Food legumes, grown for their seeds, play an important role in crop rotation with cereals in rainfall agriculture. Recently, in Morocco, food legumes have regained interest through the national agricultural strategy «Plan Maroc Vert» which aims to increase production fivefold in several regions. This suggests a greatly increased availability of grains and straws. At the national level, no work has been done to evaluate the yield and chemical composition of these residues, although elsewhere the differences in the nutritive characteristics of straws result from variations in the proportions of morphological fractions, genotype and environmental factors (Capper, 1988). These criteria can be assets in low rainfall areas where there is a large integration of livestock to agriculture and the feed resources for ruminants are limited. This study was carried out to evaluate the yield of eight Moroccan chickpea genotypes straws and to determine the chemical composition of their morphological fractions.

II – Materials and methods

Eight Moroccan chickpea genotype straws were studied including four varieties (Arifi, Douyet, Farihane, Zahour) and four promising lines (Flip97-190C, Flip 97-114C, Flip97-677C and Flip85-1C). The agronomical trial was conducted in 2016 at Jmaat Shaim experiment station. The genotypes were arranged in a randomized complete block design with four replications. Each plot was of two rows of four meters long with a spacing of 0.5 m. The total biomass was collected from each elemental plot and weighed just after harvest. The seeds were separated from the leaves and stems for each genotype and each repetition. A sample of each component of each genotype and each replicate was ground to pass through a 1 mm screen and stored for chemical analysis. Dry matter (DM) was determined by drying the samples at 50°C untill constant weight and ash by burning the samples in muffle furnace at 550°C for 4 h. Detergent fibre fractions (neutral detergent fibre (NDF), acid detergent fibre (ADF) and 72% sulfurous acid lignin residual ash (ADL)) were determined using the method of Van Soest (1967). The crude protein (CP) was determined by Kjeldahl method (Association of Official Analytical Chemists (AOAC), 1990). The analysis of the variance was completed by the Newman and Keuls mean comparison test.

III – Results and discussion

The genotype had a significant effect on the straw yield, the straw to total biomass, and leaves to straw proportions. The average straw yield was 30 q / ha with a minimum of 26.9 q / ha for Flip97-190C and a maximum of 36.3 q / ha for Flip97-677C. This straw yield corresponded to an average proportion of 60% of the total biomass. The leaves to straw proportion was on average 46.5% (Table 1) and therefore the fraction of the stems exceeded the half (53.5%). This suggests that the nutritive value of straw will depend on the chemical composition of the stem (Xing *et al.*, 1993). Except Arifi variety, others showed higher content of CP (Table 2) compared to one found (6.1% DM) by Bruno-Soares *et al.*, (2000). Beside, the recorded CP values were greater than those reported in cereal straw by Assioua (1990).

The ash content of the different genotypes was 8.85 % DM. This value was twofold of that found by Bruno-Soares *et al.*, (2000) and was higher than what was found for chickpea straw in France (Yaméogo *et al.*, 1991). Arifi variety had greatest ash content (12.2% DM) and Flip97-190C had the lowest ash content (6.9% DM). These values were close to those reported by Ben Slimane (1988) and Assioua (1990) in cereal straw

The average values of cell walls, including NDF, ADF and ADL, were 59, 40 and 10% DM respectively. These values were lower than those reported by Bruno-Soares *et al.*, (2000) (76.5, 59.6 and 14.2% DM, respectively). The lignin content of chickpea straw is almost twofold of the cereal straw (Muñoz, 1991). This suggests the low digestibility of chickpea compared to cereal straws.

Table 1. Yield of eight Moroccan chickpea genotype straws

	Straw yield (q)	Straw proportion (%)	Leaves to straw proportion (%)
Arifi	29.9^{b}	58.2^{d}	41.2^{e}
Douyet	30.7^{b}	60.6^{b}	45.4^{d}
Farihane	30.5^{b}	60.2^{c}	47.7^{c}
Zahor	28^{c}	58.2^{d}	47.6^{c}
Flip85-1C	31.1^{b}	62^{b}	44.7^{d}
Flip97-190C	26.9^{d}	61.4^{b}	49.4^{a}
Flip 97-114C	28.6^{c}	59.4^{c}	48.5^{b}
Flip97-677C	36.3^{a}	63.8^{a}	47.2^{c}
Average	30.2	60.5	46.5

Values in the same columns followed by different letters are significantly different (P < 0.05).

Table 2. Chemical composition of eight Morrocan chickpea straws

	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)
Arifi	12.2	4.4	57.8	40.1	10.2
Douyet	9.7	6.9	58.9	41.3	10.8
Farihane	9.1	7.4	57.3	38.6	10.3
Zahour	8.3	8.3	61.1	43.5	10.8
Flip85-1C	7.6	7.5	60	39.6	10.1
Flip97-190C	6.9	7.4	58.5	38.2	10
Flip 97-114C	8.7	6.3	59.7	42.3	10.6
Flip97-677C	8.3	8.9	56.8	37.8	9.9
Average	8.85	7.14	58.76	40.17	10.34

The chemical composition of different fractions varied according to the genotypes. The ash and crude protein contents of the leaves were higher than those of the stems. However, the cell wall contents (NDF, ADF and ADL) of the stems were higher than those of the leaves (Table 3). This result was in agreement with that found for other forages (Fekede *et al.*, 2008, Tan *et al.*, 1995). Arifi variety had the lowest (P < 0.05) proportion of leaves and the lowest protein content.

Table 3. Chemical composition of leaves (L) and stems (S) of eight Morrocan chickpea straws

	Ash (%DM)		CP (% DM)		NDF (% DM)		ADF (% DM)		ADL (% DM)	
	L	S	L	S	L	S	L	S	L	S
Flip85-1C	10.4^{a}	9.4^{a}	10.4^{b}	9.4^{b}	44.8^{bc}	62.2^{ab}	25.7^{bc}	47.7^{ab}	7.7^{c}	12.5^{b}
Douyet	10.7^{a}	7.1^{a}	10.7^{b}	7.1^{ab}	41.9^{b}	61.1^{ab}	25.2^{b}	45.7^{ab}	7.2^{bcd}	11.3^{ab}
Farihane	12.0^{a}	5.9^{a}	12.9^{b}	5.9^{a}	40.1^{b}	61.8^{ab}	23.9^{b}	47.1^{ab}	6.0^{ab}	12.2^{ab}
Arifi	11.9^{a}	8.0^{a}	5.4^{a}	4.3^{a}	50.1^{c}	58.3^{a}	28.3^{c}	43.8^{a}	8.3^{d}	10.6^{a}
Zahor	10.8^{a}	6.5^{a}	13.7^{b}	3.7^{a}	43.2^{bc}	61.1^{ab}	25.3^{b}	46.2^{ab}	6.8^{abc}	11.3^{ab}
Flip97– 90C	11.5^{a}	7.5^{a}	13.5^{b}	4.6^{a}	32.6^{a}	63.9^{b}	20.1^{a}	48.5^{b}	5.5^{a}	13.0^{b}
Flip97– 14C	9.2^{a}	5.2^{a}	11.2^{b}	4.1^{a}	45.5^{bc}	64.6^{b}	26.7^{bc}	48.7^{b}	6.8^{abc}	12.7^{b}
Flip97– 77C	9.2^{a}	5.2^{a}	12.4^{b}	5.5^{a}	42.9^{bc}	61.4^{ab}	25.0^{b}	46.0^{ab}	6.6^{abc}	12.1^{ab}
Average	10.7	6.8	11.3	5.6	42.6	61.8	25.0	46.7	6.9	11.9

Values in the same columns followed by different letters are significantly different (P < 0.05).

IV – Conclusions

Results obtained in this work showed significant differences between the eight Morrocan chickpea genotypes studied in straw yield, straw proportion in total biomass and leaves to straw proportion. The leaves were characterised by high protein and ash contents and lowest cell wall content than stems. These straws had an interesting productive potential and a better nutritional quality than cereal straws. Further studies are needed to determine the effect of substituting cereal straw with chickpea straw in ruminant diets.

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Chamaecytisus palmensis (Christ) Hutch. cultivated in Sardinia with different planting density

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Abstract. A population of *Chamaecytisus palmensis* (Christ) Hutch. was evaluated for its homogeneity and forage production. 300 cuttings were planted in September 2013 in 3 m spaced rows, at a row distance of 0.5 m and 1 m, with a resulting density of 6600 and 3300 plants per hectare. In the first year the trial was irrigated until March, 2014 owing to winter drought. The plant development was rather slow: planting was very water exigent and in 2015 suffered from winter cold. First utilization was possible in February 2015 and other four samplings were made until September 15, 2016, attaining an overall yields of 1 t ha^{-1}, with a better production in the highest plant density thesis. Regarding biological cycle and morphological traits, the *Chamaecytisus* population showed a large variability.

Keywords. Mediterranean habitat – Forage production.

Chamaecytisus palmensis *cultivé en Sardaigne avec différentes densités de plantation*

Résumé. *Une population de* Chamaecytisus palmensis *(Christ) Hutch. a été évaluée selon son homogénéité et son production fourragère. En septembre 2013, 300 boutures ont été plantées en rangées espacées de 3 m, les rangées espacées de 0.5 m et 1 m, avec une densité totale de 6600 et 3300 plants par hectare. Les conditions météorologiques de sécheresse de la première année ont obligé à irriguer jusqu'en mars 2014. Le développement a été plutôt lent: les plantations ont été très exigeantes en eau et ont souffert du froid hivernal en 2015. La première utilisation a été possible en février 2015 et quatre échantillonnages additionnels ont été effectués jusqu'au 15 septembre 2016, atteignant des rendements globaux de 1 t ha^{-1}, avec une meilleure production dans la thèse ayant la densité de plantes la plus élevée. La population de* Chamaecytisus *a montré une grande variabilité dans le cycle biologique et dans les traits morphologiques.*

Mots-clés. *Habitat méditerranéen – Production fourragère.*

I – Introduction

Mediterranean regions are characterized by dry-hot weather conditions in summer, resulting in lacking natural pastures and forage crops during this season. Therefore, evergreen shrubs could reduce this productive gap.

Chamaecytisus palmensis (Christ) Hutch., formerly known as tree lucerne or tagasaste, is a fast-growing, perennial, evergreen, leguminous shrub 5-6 m tall at maturity. Native from the Canary Islands, it grows well in a wide precipitation range of 350-1600 mm (Frame *et al*., 1998). It is adapted to sandy well drained soils in the pH range 5-7 and is very susceptible to root rot fungus on poorly drained soils (Gutteridge, 1990). It is susceptible to frost damages, particularly at early stages, thereby jeopardizing its potential widespread utility in the drought-prone areas (Sheppard and Bulloch, 1986). It successfully adapted to the natural conditions and is currently utilized as supplementary forage for sheep and cattle, particularly in summer and early autumn, in: (i) several temperate countries (*e.g.* New Zealand); (ii) in Mediterranean climate regions (*e.g.* Western Australia); (iii) in long, hot and dry summer regions (*e.g.* Ethiopia) (Frame *et al.*, 1998).

It is generally well branched and characterized by grey bark, hairy-velvety trifoliate leaves, fragrant whitish-coloured flowers gathered in small clusters and green flat pods that darken to maturity along with seeds.

After transplanting, the young cuttings can be grazed by livestock. Thus, they should be protected for the first years to allow a proper development. During this period, inter-row areas could be cropped for grain or hay in an alley cropping system, which could continue even after shrubs maturity (Snook,1982).

The feeding value is similar to other conserved forages but lower than intensively managed temperate pastures (Borens and Poppi,1990).

There is a considerable genetic variation within and between populations for a range of morphological and physiological traits including: production, growth habit, frost and disease tolerance. Hence, different selection programs are carried out for each trait (Douglas *et al*., 1998).

The purpose of this study was to evaluate the edible dry matter (EDM) production and the homogeneity of shrub supplied by a Sardinian farmer with the goal of registering the population in the National Register of Varieties.

II – Materials and methods

Chamaecytisus palmensis was planted in an experimental farm located in southern Sardinia (39°10' N, 3°20' E, 150 m asl), Italy, on September 24, 2013 and fertilized with 100 kg ha^{-1} of triple superphosphate.The site is characterized by a medium-deep soil limited in nutrients except for potassium (typic palexeralf soil, USDA Soil Taxonomy) and Mediterranean climatic conditions. Long term rainfall of 460 mm is distributed from October to May with a large annual and seasonal variability. Winter temperatures seldom reach 0°C, while maximum temperature average is 32°C in July.

300 rooted cuttings were placed on six rows 3 m spaced, according to the distances on the row of 1 m and 0.5 m, resulting in a plant density per hectare of 3300 (D1) and 6600 (D2), respectively.

Due to the unusual autumn-winter drought conditions, the cuttings were irrigated until March 2014. On September 16, 2014, one year after transplanting, the pruning was performed by topping and hedging the rows at 60 cm. Vegetative development was very different among plants, so they were classified in three growth degrees (good, medium and poor).

In a randomized block design, according to the two plant densities and the three observed development degrees, the test areas were settled consisting in four consecutive plants each, in order to determine the edible dry matter (EDM) production. Data on forage yield were statistically analysed with MSTAT-C software using two-way ANOVA procedure.

Samples were subdivided into twigs and leaves in order to assess protein and fiber content regardless plant density effects; near-infrared reflectance spectroscopy method (NIRS) was used. Palatability was evaluated by offering the green fodder to a group of cattle both at grazing and in the stable. Concerning the evaluation of plants uniformity, periodical observations were made during the biological cycle and the phenological phases.

III – Results and discussion

The development of *Chamaecytisus palmensis* was quite slow. After transplanting, it proved to be very exigent for irrigation and suffered from cold in the following winter.

Five samplings were made during the first two years. First sampling was made on February 18, 2015, eighteen months after transplanting. At this date some plants began flowering. The successive samplings were made on: 27 May, 2015 and 15 September, 2015; 13 February, 2016 and 15 September, 2016. The overall EDM production was 0.7 t ha^{-1} on D1 and 1.3 t ha^{-1} on D2.

Statistical analysis did not show any significant difference, both for plant density and development degrees. In contrast, D2 thesis proved to be higher yielding than D1 although this difference in not statistically significant due to the high coefficient of variation (CV) (table 1).

Table 1. Total EDM production of the 5 samplings performed in the first two years

Degree of development and plant density	EDM g m^{-2}	Plant density	EDM t ha^{-1}
Poor D1	16.9	D1 (1 m on the row)	0.7
Poor D2	64.1	D2 (50 cm on the row)	1.3
Good D1	111.4	Statistical significance.	n.s.
Good D2	212.3	CV	28.4
Medium D1	79.8		
Medium D2	103.8		
Statistical significance	n.s.		

Chemical analysis of EDM revealed a medium crude protein content of 12.7% and 17.7% in twigs and leaves, respectively. Conversely, fibre content was higher in twigs (table 2). The protein content does not seem to be very appreciable compared to other typical species of herbaceous Mediterranean legumes (eg. *Medicago polymorha* 25-32%) (Vargiu *et al.,* 2018), but it is important to consider its availability in periods with scarce forage resources such as summer and winter (Papanastasis *et al*., 2008).

Table 2. Crude protein and fibre content (%) of leaves and twigs

Part of plant	Proteins	NDF	ADF	ADL
Twigs	12.7	49.7	36.2	7.6
Leaves	17.7	37.9	25.6	8.5

Forage production did not seem much palatable for cattle: when cut and left on the field for grazing, it was refused. Oppositely it was consumed in stable, although very slowly.

All plants showed great differences in: flowering time, habitus, development and in the green tonality of leaves. North-oriented and wind exposed plants have always shown a more withered and less leafy habitus. Flowering date was very variable, from January to June, both within plants and mostly among plants. Pollinating insects and bees seemed to be particularly attracted by *Chamaecytisus palmensis* flowers.

IV – Conclusions

Regarding plant density and development degree, *Chamaecytisus palmensis* population showed no significant differences in forage yield, between D1 and D2. Moreover, lacking phenotypic and phenological uniformity, will very likely prevent this population to be registered by the Sardinian farmers.

However, further selections of the best biotypes could be carried out for, despite the initial slow development, this population could be attractive as a feed supplement in the periods of shortage of forage resources on conditions that the local cattle get used to its taste.

The interest in multi-use should also be mentioned. As an example, it could be extensively used as a windbreak or protection belt in arid regions. Furthermore, its dense wood suggests an interest for firewood (Gutteridge and Shelton, 1998). Finally, given the long duration of flowering period, it could be interesting both for the furnishings of parks, gardens as well as for honey production.

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Use of Sulla flexuosa *(Hedysarum flexuosum)* by breeders in Kabylia (Algeria)

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Abstract. *Hedysarum flexuosum* (Sulla flexuosa) is a forage legume endemic to North Africa and south of Europe. Unfortunately, although its nutritional value, equal or even higher than alfalfa, this resource is classified as endangered because it spontaneously grows and is not cultivated. However, it could play a leading role in the resorption of the fodder deficit in Algeria. In order to contribute to the conservation of Sulla flexuosa, the collection of information on the uses of this legume by the populations is one of the most important stages. For this, from April to May 2018, an investigation focusing on the use of this legume was carried out by individual interviews of 105 breeders spread throughout the Tizi-Ouzou region in Algeria. The Sulla is reported in about twenty communes (districts) across the wilaya (region) where its appearance is mostly noticed by farmers in December (19.8%) or February (20.7%). For half of the breeders, Sulla grows mainly on sloping ground. While the vast majority (84%) distinguish between the two forms (plagiotropic or orthotropic), only about half (45.3%) maintain that it is biennial and nearly one-third (34%) think it is annual. It is the totality of the breeders who uses it in animal feeding and which signal its use also in human food. In animal feed, three quarters of breeders use it as green (feeding to the trough or pasture). The combination of the scientific research results combined with traditional and ancestral knowledge must be the basis of all breeding and genetic improvement programs leading to domestication of H. *flexuosum*.

Keywords. Sulla flexuosa – Fodder – Breeding – Kabylia – Algeria.

Utilisation du Sulla flexuosa* (Hedysarum flexuosum) *par les éleveurs en Kabylie (Algérie)

Résumé. *Le Sulla flexuosa* (Hedysarum flexuosum) *est une légumineuse fourragère, endémique du Nord de l´Afrique et le Sud de l´Europe. Bien que sa valeur nutritive soit égale ou supérieure à la luzerne, cette espèce est classée en voie de disparition du fait qu'elle pousse d'une manière spontanée et n'est pas cultivée. Dans l'objectif de contribuer à la conservation du Sulla flexuosa* (Hedysarum flexuosum)*, le recueil d'informations sur les usages de cette légumineuse par les populations est une des étapes les plus importantes.Une enquête ethnobotanique mettant l'accent sur l'usage fourrager de cette espèce a été réalisée en 2018 par interviews individuelles de 105 éleveurs répartis sur la wilaya de Tizi-Ouzou. Le Sulla est signalé dans une vingtaine de communes à travers la wilaya où son apparition est surtout remarquée par les éleveurs en Décembre (19,8 %) voire en Février (20, 7%). Pour la moitié des éleveurs, le Sulla pousse surtout sur les terrains en pente. Si la grande majorité (84%) distingue les deux formes plagiotrope et orthotrope, seulement près de la moitié (45,3%) soutiennent qu'elle est bisannuelle et près d'un tiers (34%) pensent qu'elle est annuelle. La totalité des éleveurs l'utilise en alimentation animale et signalent son utilisation aussi en alimentation humaine. En alimentation animale, trois quart des éleveurs l'utilise en vert (affourragement à l'auge ou pâturage). La conjugaison des résultats de la recherche scientifique (sur la morphologie, la phénologie, la biochimie et la valeur nutritive) et du savoir traditionnel et ancestral doit être le socle de tous les programmes de préservation, de sélection, d'amélioration génétique débouchant sur la domestication de* H. flexuosum.

Mots-clés. *Sulla flexuosa – Savoir ethnobotanique – Alimentation – Élevage – Kabylie – Algérie.*

I – Introduction

In Algeria, spontaneous flora is estimated by Abdelguerfi and Ramdane (2003) at about 3139 species. Most of the forage and pastoral resources come from natural environment (Abdelguerfi *et al*., 2000). To enrich the knowledge of useful spontaneous species, ethnobotanical surveys are necessary

(Kébenzikato *et al*., 2015). The genus *Hedysarum* is composed of a large number of species including annual and perennial forage, widely distributed around the world (Le Houérou, 2001). In Algeria, there are several species that are highly localized (Abdelguerfi-Berrekia *et al*., 1988). Among these species, *Hedysarum flexuosum* characterized by an Ibero-North African distribution (Ben fadhel *et al*., 2006), endemic to north-central Algeria (Abdelguerfi-Berrakia *et al*., 1991) and develops in regions with average rainfall greater than 550 mm (Abdelguerfi and Laouar, 1999). This legume could play a major role in reducing the fodder deficit in the country. Unfortunately, although it's nutritional value is equal or even higher than alfalfa (Kadi *et al*., 2011; 2012; Zirmi-Zembri and Kadi, 2016), this resource is classified as endangered (Groom, 2012) because it grows spontaneously and is not cultivated. In order to contribute to the conservation of Sulla flexuosa by its valorization, the collection of information on the uses of this legume by the populations is one of the most important stages.

II – Materials and methods

This study was carried out on the whole territory of the wilaya (district) of Tizi-Ouzou (http://wilaya-tiziouzou.dz/), which is located between 36°43 'and 36°91' of latitude North and between 3°79' and 4°72' of longitude East and which covers an area of 3993 Km^2. It is located in the north of Algeria, 100 km east of the capital Algiers. This wilaya has one of the highest afforestation rates in the country (38%), due to favorable bioclimatic conditions (subhumid and humid), is mostly mountainous relief. For geographical and historical reasons, it has remained relatively isolated and agro-industrial development has not led to a significant decline in customary practices (Meddour *et al*., 2009).

Firstly, we carried out a pre-survey coupled with a bibliographical search on the presence of *Hedysarum flexuosum* at the Tizi-Ouzou wilaya. In addition, we used the database created on this legume at our laboratory of animal nutrition and animal products at the Department of Agronomy at the Faculty of Biological and Agronomic Sciences of the Mouloud Mammeri University of Tizi-Ouzou.

It includes questions on the different uses of Sulla flexuosa in the food, feed and medicinal fields. Survey fact sheets have been drawn up which provide information on Sulla identification by farmers, the various uses of Sulla for human and animal consumption and long-term prospects and strategies. In this paper, only the aspect relating to the forage character of the plant will be developed. The data were collected from April to May 2018 through direct and individual interviews of 105 breeders taken at random.

The data collected was coded and entered into a spreadsheet file on the Microsoft EXCEL® 2013 software. For this preliminary study, only the frequency calculation was used using the Stat Box® V.6.4 software.

III – Results and discussion

A total of 105 survey cards were completed. The majority of respondents are over 30 (73.58%) and male (100%). The Sulla is reported in twenty communes (sub-district) out of the 67 in the wilaya.

The plants of Sulla flexuosa are noticed by the breeders especially in December (near 20%) or in February (close to 21%). 52% of breeders were reported from September to December (Fig. 1). This difference in the date of appearance of Sulla can be explained by the fact that germination of this plant dependent on the first autumn rains which must be early and abundant for the emergence of integumentary dormancy. According to Medjebeur *et al*. (2018), the delay in germination increases with the severity of both water and salt stress.

For half of the farmers (51.8%), Sulla grows mainly on sloping land, and for one third (37.74%) of them, it is present on plots with a mixed relief of the flat and the slope. Only one-tenth of breeders (10%) encounter it on flat soils only (Fig. 2). According to Abdelguerfi-Berrekia *et al*. (1991), H. flexuosum is able to provide very interesting yields on sloping marl soils, soils with difficult and marginal topography and low productive potential.

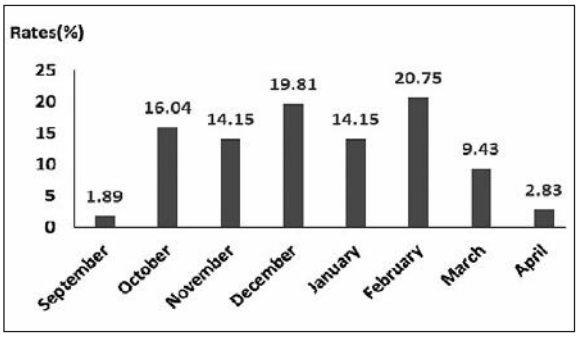

Fig. 1. Month of appearance of Sulla flexuosa in the study area according to the breeders.

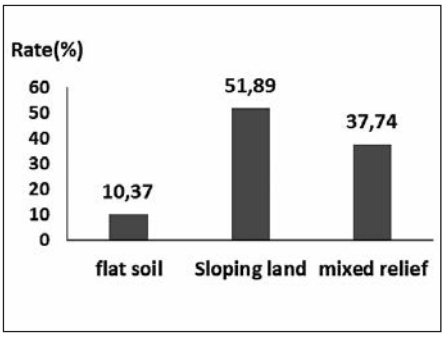

Fig. 2. Frequency of the different reliefs of plots in Sulla flexuosa according to the breeders.

The vast majority of breeders (84%) distinguish the two plagiotropic and orthotropic forms of Sulla populations (Fig. 3) irrespective of the region, which corroborates the results of Ben Fadhel *et al*. (2006) for which, the Algerian populations of Sulla flexuosa are distinguished in particular by an erected port with intense branching and leaves with a large number of leaflets. This character is of great importance for the exploitation of this forage by allowing modes of manual and / or mechanical mowing. The plants with strict plagiotropic ports are only present by 2.83% of the breeders surveyed against 13.21% of strictly erect (orthotropic) plants.

Nearly half of the respondents (45.3%) say that Sulla flexuosa is biannual and nearly one third (34%) think it is annual (Fig. 4). The irregularity of appearance of this forage species is related to the abiotic factors of the region and mainly the precocity and the intensity of the precipitations. According to Bell *et al*. (2003), Sulla flexuosa is an annual species and the degree of seed softening in Hedysarum sp. is an important selection criterion in the development of new cultivars.

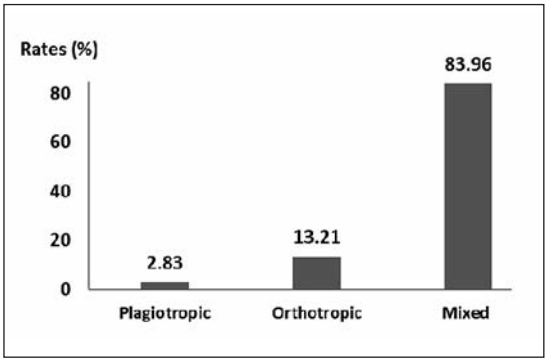

Fig. 3. Frequency of the different architectures of Sulla flexuosa according to breeders.

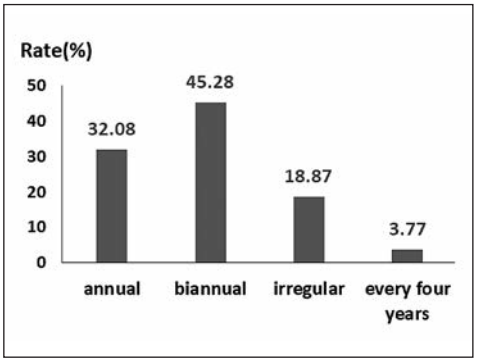

Fig. 4. Frequency of cyclicality of Sulla flexuosa according to breeders.

All the breeders surveyed use *Hedysarum flexuosum* for animal feed but also indicates its use in human nutrition.

In animal feed, three quarters of breeders (75%) use it in green, whether for feeding at the trough or grazing (Fig. 5). Natural populations of *Hedysarum flexuosum* provide winter and spring grazing with good nutritional value (Abdelguerfi-Berrakia *et al*., 1991). Around the world, the use of Sulla is reported in sheep feeding (Bonanno *et al*., 2011), goats (Di Trana *et al*., 2015), cows (Chaves *et al*., 2006) and rabbits (Kadi *et al*., 2011 and 2012). This legume is an effective example of a multipurpose species also exploited for environmental protection, landscape enhancement and honey production (Jerković *et al*., 2010).

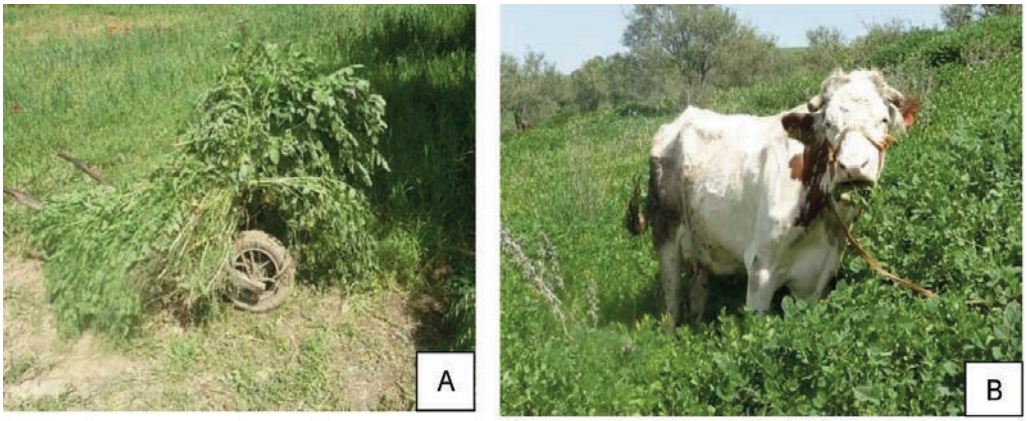

Fig. 5. Use in green *H. flexuosum*, the most popular mode in the study area. A: harvested for feeding at the trough. B: In pasture.

IV – Conclusions

Sulla flexuosa, spontaneous forage resource, is widely used in livestock feeding in this rearing area. It is used in green, pasture or forage at the trough and / or dry in the form of hay.

In a context of global warming and the need to ensure food security, it is imperative to implement the means necessary for its domestication and recovery.

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iSAGE Workshop on Innovations for Sustainable Sheep and Goat Systems / Miscelanea

Genomic bases of local adaptation in sheep and goats

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Abstract. Since their domestication 10.000 years ago followed by a worldwide spread, sheep and goats have accumulated highly valuable adaptive traits allowing them to be raised across highly diverse environments. Besides the current rapid development and wide spread of just a few productive cosmopolitan breeds marked by limited genetic diversity, indigenous populations may keep adaptive traits that would constitute key genomic resources in the context of environmental changes. Within the EU-FP7 funded NextGen project, we applied a landscape genomics framework to identify genes involved in local adaptation. We sequenced the genomes of 160 indigenous sheep and 161 goats representative of the Moroccan-wide diversity in ecology, climate and geographic origin. We detected 39 million variants in sheep and 32 million in goats showing a very weak geographic structure over the country in both species. Using different approaches we identified several sets of loci and genes that likely have a role in local adaptation globally to altitude, slope, sunshine, rainfall, temperature and their variation. The main adaptive pathways were associated with respiration and circulation for the adaptation to altitude. The major genes identified showed different patterns of variation of allele frequencies along environmental gradients. Candidate genes for adaptation to the same environmental variable were generally different between the two species, suggesting different adaptive mechanisms in sheep and goats. However, similar or functionally linked genes responding to the same environmental variable were also found. Results from this study would help in setting up efficient plans of genomic selection based on adaptive traits and be then of major interest for a sustainable management of genetic resources in sheep and goats.

Keywords. Sheep – Goats – Local breeds – Adaptation – Genomics.

Bases génomiques de l'adaptation locale chez les ovi-caprinés

***Résumé**. Depuis leur domestication il y a 10 000 years, suivis d'une propagation dans le monde entier, les ovins et les caprins ont accumulé des traits adaptatifs très précieux leur permettant d'être élevés dans des environnements très diversifiés. En dépit du développement rapide actuel et la large diffusion de quelques races cosmopolites productives caractérisées par une diversité génétique limitée, les populations autochtones peuvent conserver des caractéristiques d'adaptation qui constitueraient des ressources génomiques essentielles dans le contexte des changements environnementaux. Dans le cadre du projet de l'UE FP7 NextGen, nous avons appliqué un cadre de génomique du paysage pour identifier les gènes impliqués dans l'adaptation locale. Nous avons séquencé les génomes de 160 moutons et 161 chèvres indigènes, représentatifs de la diversité écologique, climatique et géographique de l'ensemble du Maroc. Nous avons détecté 39 millions de variantes chez le mouton et 32 millions chez la chèvre, présentant une structure géographique très faible sur le pays chez les deux espèces. En utilisant différentes approches, nous avons identifié plusieurs ensembles de locus et de gènes qui jouent probablement un rôle dans l'adaptation locale à l'altitude, à la pente, à l'ensoleillement, aux précipitations, à la température et à leurs variations. Les principales voies d'adaptation étaient associées à la respiration et à la circulation pour l'adaptation à l'altitude. Les gènes candidats à l'adaptation à la même variable environnementale étaient généralement différents entre les deux espèces. Cependant, des gènes similaires répondant à la même variable environnementale ont également été trouvés. Les résultats de cette étude présenteraient un intérêt majeur pour une gestion durable des ressources génétiques chez les ovins et les caprins.*

***Mots-clés.** Ovin – Caprins – Races locales – Adaptation – Génomique.*

I – Introduction

Threats to biodiversity in farm animals are increasing, both in terms of extinction rates and destruction of agro-ecosystems, or the loss of genetic diversity. Indeed, the formulation of the modern breed concept during the mid-1800s (Porter 2002) and its application to breeding and its practices led to the formation of well-defined breeds and their exposure to strong artificial selection. The development of farming practices such as artificial insemination and embryo transfer, feeding techniques and the use of vaccines and treatments against endemic diseases have allowed the spread of industrial livestock farming. This has led breeders to gradually replace indigenous breeds, well adapted to local conditions, with highly productive cosmopolitan breeds (Taberlet *et al.,* 2008). As a result, a significant number of sheep and goat breeds have become extinct and several other breeds are endangered (Altshuler *et al*., 2012). In a context of climate change, indigenous breeds that are well adapted to their farming conditions constitute a capital asset of adaptive alleles. Similarly, understanding the mechanisms involved in the processes of their adaptation could have major repercussions and practical applications for the management and preservation of livestock genetic resources. This paper aims to understand the process of adaptation of goats and sheep to different environmental conditions with innovative approaches of genomics. More specifically, it aims at identifying sets of loci putatively related to local adaptation in both species.

II – Materials and methods

1. Data production, processing and analysis

Following the wide sampling of sheep and goats in Morocco and the establishment of the representative sample bank of these species in Morocco (1412 sheep and 1283 goats), 160 sheep and 161 goats were chosen so as to have the widest distribution of animals in terms of geo-climatic variables, as explained below. These individuals were subjected to DNA extraction and sequencing of their entire genomes on an Illumina® Hi-Seq 2000 platform in order to have a minimum coverage rate of 10x. As described by Benjelloun *et al*. (2015), Illumina paired-end reads for sheep were mapped to the sheep reference genome (OAR v3.1, GenBank assembly GCA_000317765.1 (Jiang *et al*., 2014)) and those for goats were mapped to the goat reference genome (CHIR v1.0, GenBank assembly GCA_000317765.1 (Dong *et al*.)) using BWA mem (Li and Durbin). The BAM files produced were then sorted using Picard SortSam and improved using Picard Markduplicates (http://picard.sourceforge.net), GATK RealignerTargetCreator, GATK IndelRealigner (DePristo *et al*.) and Samtools calmd (Li *et al*., 2009). Variant calling was done using three different algorithms: Samtools mpileup, GATK UnifiedGenotyper (McKenna *et al*., 2010) and Freebayes. Genotypes were improved and phased by Beagle 4 (Browning and Browning, 2013).

2. Neutral genetic diversity

Neutral genomic variation was calculated to evaluate the level of genetic diversity present in Moroccan sheep and goats. The total number of variants and the number of variants within each population were calculated. The level of nucleotide diversity (π) was calculated in each species and averaged over all of the biallelic and fully diploid variants for which all individuals had a called genotype using Vcftools (Danecek *et al*.). Pairwise linkage disequilibrium (LD) was assessed through the correlation coefficient (r2). It was estimated in 5 segments of 2Mb on different chromosomes (physical positions between 5 Mb and 7 Mb on chromosomes 6, 11, 16, 21 and 26). LD was estimated either by using the whole set of reliable variants or after discarding rare variants with a minor allele frequency (MAF) less than 0.05. For both estimations, r2 values between all pairs of biallelic variants (SNPs and indels) on the same segment were calculated using Vcftools. Inter-SNP

distances (kb) were binned into the following 7 classes: 0-0.2, 0.2-1, 1-2, 2-10, 10-30, 30-60 and 60-120 kb and observed pairwise LD was averaged for each inter-SNP distance class and used to draw LD decay.

3. Adaptive genomic variation

A genome scan method based on population genetics models was applied on our datasets. We worked on 7 variables representing various environmental categories, i.e. climatic variables temperature, precipitations and DEM-derived altitude and slope with their respective original resolutions. For each variable, two pools of 20 individuals were constituted, each representing one extreme of the gradient of variation of the variable. The XP-CLR method (Chen *et al.,* 2010) was then run to identify potential regions differentially selected in each extreme pool. It is a likelihood method for detecting selective sweeps that involves jointly modelling the multi-locus allele frequency differentiation between two populations. It is based on a reference population and an object one. This test was combined to a single-locus *Fst* test (Weir and Cockerham 1984) to detect selective sweeps identified by both approaches.

For each species we aimed at depicting the pattern of differentiation of the top candidate genes under selection across the environmental gradients. For that, for each environmental variable we ranked the 160 sheep (and 161 goats, respectively) according to the ranking of their geographic position on the environmental gradient considered. A sliding limit moving by steps of 10 individuals was applied to define 2 groups among which the *Fst* value (Weir and Cockerham 1984) was estimated based on the candidate variants associated to those genes. The minimum number of individuals per group was 20 and the maximum 140. Then, this allowed plotting the variation of the *Fst* value along the environmental gradient.

III – Results and discussion

1. Neutral genomic diversity

We mapped unambiguously 99.4% (± 0.1%) of sheep reads on the OAR v3.1 assembly and 98.9% (± 0.1%) of goat reads on the CHIR v1.0 assembly. 38,599,873 variants were successfully called in sheep, among which 38,278,356 were polymorphic. For goats, 31,743,850 variants were discovered in the total dataset among which 31,650,083 were polymorphic. The whole genome nucleotide diversity was 0.174 in sheep and 0.126 in goats. Linkage disequilibrium was assessed by the pairwise r^2 value between polymorphic sites in the studied genomic regions. Using the whole set of reliable variants, the genomic distance at which it decayed to less than 0.15 was 655 bp in sheep and 166 bp in goats. Moreover, r^2 decayed to less than 0.1 in 3.12 kb and 2.1 kb in sheep and goats respectively. When withdrawing rare variants (MAF<0.05), the average r^2 decayed to less than 0.2 in 3.6 kb in sheep and 5.8 kb in goats. It decayed to less than 0.15 in 4.4 kb in sheep and 8.1 kb in goats.

Sheep and goats displayed very large counts of genomic variants (38.6 M and 31.7 M respectively) enlarging substantially the worldwide catalogue of ovine and caprine variants. Sheep showed 6.9 million more variants than goats, with a higher nucleotide diversity that could be linked to a higher percentage of rare variants in goats. Linkage disequilibrium was slightly lower in goats. However, *LD* value is highly influenced by the percentage of rare variants and, when we removed them, sheep displayed even lower *LD*. This fact could also partly explain differences in heterozygosity and inbreeding coefficients between the two species. Generally, *LD* extents found here complete on one hand the findings of Benjelloun *et al*. (2015) who found a longer *LD* extent ($r^2_{0.15}$=1.33kb using the whole set of variants and $r^2_{0.15}$≈12 kb when excluding rare variants) using a subset of our goat dataset. The difference in reported *LD* results from the fact that we used here many more animals

for that estimate. On the other hand, *LD* values reported here are shorter than all those reported on other domestic animals (i.e. horses, cattle, pigs) where it largely exceeds 10 kb for r^2=0.20 (Villa-Angulo *et al.,*. 2009; Wade *et al*., 2009). Our results would illustrate a large effective population size and the effect of the very common extensive breeding systems favouring high gene flows among Moroccan sheep and goats and the absence until now of very strong selection pressure. This was particularly suitable for identifying selective sweeps likely associated to local adaptation.

2. Genomic bases of local adaptation

Combining the XP-CLR and *Fst* methods, we highlighted 5981 (± 746) different candidate variants and 141 (± 20) different candidate genes on average in each one of the 5 studied variables in sheep (Table 1) and 4930 (± 564) candidate variants and 214 (± 25) candidate genes in each extreme group for the 5 studied variables in goats (Table 1). In sheep, we identified 136 candidate genes related to altitude and 112 candidate genes were identified for rainfall in April. Similarly, 165 genes were identified for temperature annual range (bio7), 150 genes for mean temperature of July (temp7) and 144 genes were identified for slope (Table 1). Candidate genes in goats were 252 for altitude, 209 for rainfall in March (prec3), 201 for rainfall seasonality (bio15), 221 for mean temperature of July (temp7) and 185 genes for slope (Table 1).

Table 1. Number of candidate genes and variants under positive selection detected in Moroccan sheep and goats in relation with 7 environmental variables

	Mean ± SD	Altitude	Rainfall in March	Rainfall in April	Temp. annual range	Rainfall seasonality	Mean temp. July	Slope
Sheep								
No. of genes	141±20	136	–	112	165	–	150	144
No. of variants	5981±746	5436	–	6250	5811	–	7133	5275
Goats								
No. of genes	214±25	252	209	–	–	201	221	185
No. of variants	4930±564	5408	4963	–	–	5470	4719	4090

The differentiation of the identified variants and genes along environmental gradients showed different patterns, generally with a highest differentiation close to one or both extremes of the gradient forming “U” or “S” shapes (Fig. 1).

Most of the identified genes were directly associated to biological processes related to the resistance to extreme levels of the environmental parameter to which they were linked. The case of genes *NFIB* and *GATA6* that were associated to altitude in goats are involved in Clara cell differentiation. This is consistent with the nature of these cells, which are epithelial on the luminal surface of airways of the mammalian lung. In addition to their secretory and xenobiotic roles, they are the progenitor cells in small pulmonary airways (Giangreco *et al*., 2002). They were shown to be numerous and prominent with big apical caps in llama living at high altitude (Heath *et al*., 1976). They presented also signs of pathological alteration and marks of their compensatory proliferation after exposure to hypoxia in rabbits (Uhlik *et al*., 2005). Other processes identified in goats for altitude comprise circulatory mechanisms that are useful in hypoxia conditions. From another hand, genes associated with ATP biosynthetic processes that have been identified for adaptation of goats to slope is consistent with a higher need for synthesised energy in animals raised in steep slopes (mountainous areas) in comparison with moderate-slope goats.

In sheep, genes associated to altitude are mainly related to the regulation of leucocyte, lymphocyte and mononuclear proliferation. Indeed, leukocyte invasion into hypoxic tissues is well-known

and circulating monocytes and/or mononuclear fibrocytes are recruited to the pulmonary circulation of chronically hypoxic animals. These cells play an important role to face the pulmonary hypertensive process in response to low-input oxygen conditions (Stenmark *et al.*, 2005). This suggests that regulation of leukocyte, lymphocyte and mononuclear proliferation would be implied in sheep adaptation to high-altitude and genes enriched in these categories (*CLCF1*, *TMIGD2*, *ZP4*, *TLR4*, *KITLG* and *EBI3*) may play a certain role in this adaptation through the mechanism cited above. Several other cases of genes are under study.

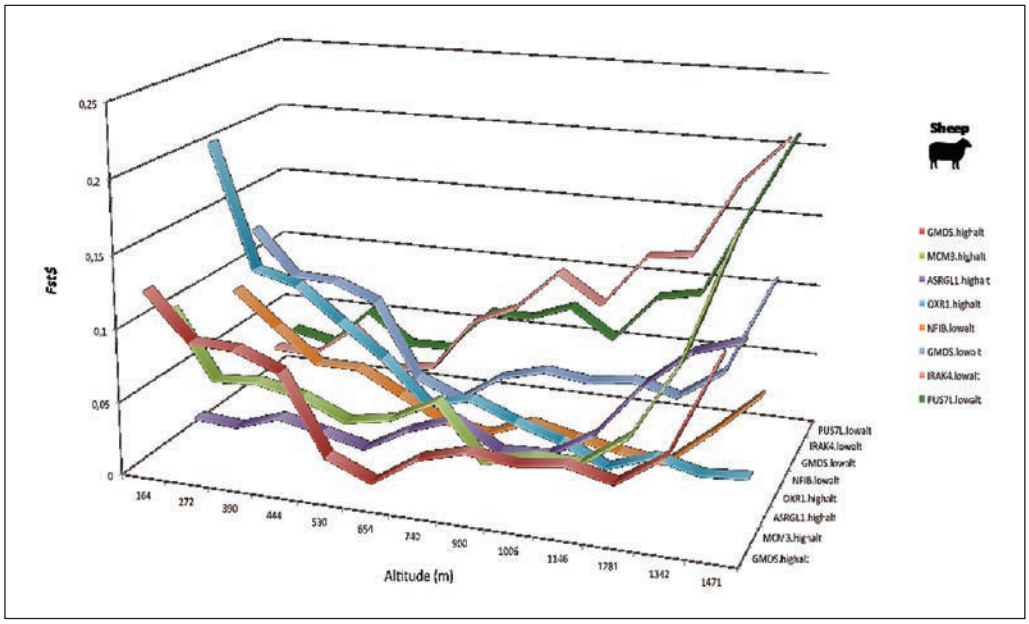

Fig. 1. Evolution of differentiation index (*Fst*) for a sliding limit along an altitudinal gradient in the eight top-score candidate genes identified in sheep.

IV – Conclusion

Our study used a landscape genomic framework to depict the genetic bases of local adaptation in farm animals. The 321 sheep and goat whole genome sequences, collected from a wide range of biotic and abiotic conditions, represent a unique resource for studying evolutionary processes. We identified several sets of candidate variants, genes and biological processes that are likely involved in local adaptation to various eco-climatic conditions. Several other genes and biological processes are under study. Therefore, this study showed the effect of local adaptation on genomes in two livestock species. This contributes to our understanding on how local adaptation could act and opened new horizons for a sustainable management of the worldwide sheep and goats.

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Marker assisted selection in Rasa Aragonesa sheep breed by using a SNP panel for parentage assignment

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Abstract. Accurate pedigree information is an essential tool in genetic breeding programs to ensure the highest rate of genetic gain and allow the management of inbreeding. In this sense, a panel of 192 SNPs, that included 153 SNPs for parentage assignment and 39 functional SNPs, is being used in the selection program for prolificacy of the Cooperative Oviaragon-Grupo Pastores in Rasa Aragonesa. Preselection of some young rams before entering progeny testing is being performed using some of the functional SNPs. For example, the *FecX*^{R} allele of the *BMP15* associated to increased prolificacy, and the *PrnP* genotypes related to scrapie susceptibility. Recently, four SNPs of the *MNTR1A* and *LEPR* genes associated to seasonality traits in Rasa Aragonesa have been included in the panel of 192 SNPs. Because of the increasing demand for hormone-free products and the evolution of European rules and directives towards a reduction, even a complete cessation of use of exogenous hormones leads to search for alternative methods such as the use of genetic markers which would be a powerful tool in selection programs. Therefore, the first objective of this research was to assess how to select some new SNPs for this SNP custom panel. Secondly, this research also aims to validate some putative causal SNPs using the SNP panel as a proof of concept.

Keywords. Rasa Aragonesa – Prolificacy – SNP – Selection.

Sélection assistée par marqueurs chez la race Rasa Aragonesa à l'aide d´un panel de SNPs pour l'assignation de parenté

Résumé. *La précision de l'information du pedigree constitue un outil essentiel dans les programmes de sélection génétique permettant d'assurer un gain génétique plus élevé et de gérer la consanguinité. Dans ce sens, un panel de 192 SNPs dont 153 SNPs d'assignation de parenté et 39 SNPs fonctionnels, a été utilisé dans le programme de sélection sur la prolificité au sein de la race Rasa Aragonesa, mené par la Coopérative Oviaragon-Grupo Pastores. Avant de commencer les tests de descendance, certains jeunes béliers sont présélectionnés à l'aide de certains SNPs fonctionnels notamment, l'allèle FecX*^{R} *du BMP15 associé à une prolificité accrue, et les génotypes PrnP liés à la susceptibilité à la tremblante. Récemment, quatre SNPs de MNTR1A et LEPR associés à des caractères de saisonnalité reproductive chez Rasa Aragonesa, ont été inclus dans le panel de 192 SNPs. En raison de la demande croissante des produits sans hormones et de l'évolution des normes et des directives européennes en vue d'une réduction, voir même une cessation complète de l'utilisation d'hormones exogènes, l'utilisation de marqueurs génétiques pourrait être une alternative et un outil puissant dans les programmes de sélection. Ainsi, l'objectif de cette recherche est d'évaluer comment sélectionner de nouveaux SNPs pour ce panel de SNP et de valider certains SNPs causaux putatifs, en utilisant le panel de SNP comme preuve de concept.*

Mots-clés. *Rasa Aragonesa – Prolificité – SNP – Selection.*

I – Introduction

Rasa Aragonesa is an autochthonous Mediterranean sheep breed from the northeast of Spain, mainly reared in extensive or semi-extensive farming systems and oriented to meat production. Improvement of farms efficiency is possible by genetics, nutrition and management approaches. In this context, the cooperative Oviaragon-Grupo Pastores carries out since 1994 a selection program for prolificacy in Rasa Aragonesa since the number of lambs born per ewe has a key role in the economic profit and viability of these farms. However, new selection objectives, as maternal ability, are being developed to improve the breed whole efficiency.

Accurate pedigree information is an essential tool in genetic breeding programs to ensure accurate estimated breeding values and genetic response and allow the management of inbreeding. However, the proportion of known sires is usually very low in Spanish meat sheep populations, particularly in breeds reared in high mountain areas such as in the Pyrenees. Single nucleotide polymorphisms (SNPs) are now the DNA markers of choice for parentage assignment. In this sense, we developed a SNP assay to be used in some North-Eastern Spanish meat sheep populations for accurate pedigree assignment (Calvo *et al*., 2018a). This panel is composed by 153 SNPs for parentage assignment, and 39 functional SNPs related to prolificacy, seasonality, scrapie resistance, and others. The selection of these SNPs is based on validated SNPs of different traits (*PrnP*, *BMP15*, *GDF9* or *MTNR1A*), or putative functional causal SNPs included in the panel for study and validation. Therefore, the first objective of this research was to show how to select some new SNPs for the SNP panel. Secondly, to validate some putative causal SNPs using the SNP panel as a proof of concept.

II – Material and methods

1. Animal Samples

For the first objective, an experimental population with phenotypic seasonality data was used. Sheep breeds from the Mediterranean area have a seasonality of breeding activity, showing seasonal patterns of oestrous behaviour and ovulation during spring (from March to July). The spring ovulatory activity has heritability and repeatability values of 0.20 and 0.30, respectively (Hanocq *et al*., 1999), but it is only measured in females, is exhibited relatively late in ewe's life and only in some management systems.

Phenotypic seasonality data were obtained from a Rasa Aragonesa sheep flock managed in an experimental farm ("Pardina de Ayés") owned by Oviaragón S.C.L., and described in Martinez-Royo *et al*. (2017). The experimental period extends from January to August of 2012. The flock was composed of 239 ewes in two age groups: young (all: 1.9 years, n=84) and mature (5.2-7.2 years, n=155; 5.5 ± 0.5; mean ± SD) at the beginning of the experiment. Individual live weight (LW) and body condition score (BCS) on a 1 to 5 scale (Russel *et al*., 1969) were assessed every three weeks. These ewes were managed in a single lot and subjected to the same nutrition and environmental conditions as described in Martinez-Royo *et al*. (2017). Three reproductive seasonality traits were considered and described in Martinez-Royo *et al*. (2017). Briefly, the first one was the total days of anoestrus (TDA), based on weekly individual plasma progesterone levels. TDA was the sum of days in anoestrus, considering anoestrus those periods with three or more consecutive progesterone concentrations lower than 0.5 ng/ml. The second reproductive seasonality trait was the progesterone cycling months (P4CM), defined for each ewe as the rate of cycling months based on progesterone determinations. When progesterone level was higher or equal than 0.5 ng/ml in at least one blood sample in that month, the ewe was considered cyclic in that particular month. Finally, the third reproductive seasonality trait considered was the oestrus cycling months (OCM), defined as the rate of months cycling based on daily oestrous records for each ewe. When

at least one oestrus was recorded in that month, an ewe was considered cyclic in that particular month. Eight vasectomised rams fitted with harnesses and marking crayons were joined with the ewes, and daily oestrous detection was performed. Thus, after natural mating, oestrus was recorded as a colour mark on the rump of the ewes.

A total of 3200 ewes from 5 flocks have been genotyped using the SNP panel, mainly for parentage assignment purpose. Phenotypic data related to prolificacy, fertility, seasonality, and the age at first lambing (AFL) were collected. However, we do not have phenotypic data for all animals. Currently, we have data for prolificacy in the whole population and for the age at first lambing. As a proof of concept, we have used a total of 351 ewes phenotyped for AFL. For this phenotype, 191,114 first lambing records (ewes without hormonal treatments) from 327 farms were analyzed using the GLM procedure (SAS) and were corrected for environmental effects. The model included *FecX*^{R} genotype, farm, month and year of the first lambing as fixed effect. Model residuals were used in the association studies.

2. Sampling and genotyping

Only two genes affecting reproductive seasonality traits have been successfully identified, the melatonin receptor subtype 1A (*MTNR1A*) (Pelletier *et al*., 2000; Mura *et al*., 2014), and the arylalkylamine Nacetyltransferase (*AANAT*) (Ding-ping *et al*., 2012). *MTNR1A* has been repeatedly proposed as candidate gene and seems to play a key role in the control of photoperiod-induced seasonality mediated by the circadian concentrations of melatonin (Notter and Cockett., 2005). In this sense, the effects of this gene have been validated in Rasa aragonesa sheep breed (Calvo *et al*., 2018b), and three SNPs of this gene were included in the SNP panel. Moreover, other candidate genes that could be related to seasonality traits were studied. Leptin, a protein secreted mainly by fat tissue, is important in appetite control, energy balance and reproduction (Taheri and Parham., 2016). Leptin´s physiological effects on reproduction including puberty, estrous cycle, pregnancy, lactation, and even the early stages of embryo development have been proven. Polymorphisms in leptin receptor gene (*LEPR*) have been associated with delayed onset of puberty and with decreased ovulation and lambing rates in prolific Davisdale sheep (Juengel *et al*., 2016).

Genomic DNA was extracted from blood samples of 268 ewes (125 and 78 mature and young ewes respectively) from the total ewes of the flock using standard protocols. Some ewes were not considered because of missing data in some variables. For *LEPR* gene, PCR products from exons 4 and 20 of 20 ewes with extreme phenotype values for the TDA and OCM were used to search polymorphisms in the experimental population. Standard protocols for PCR amplification and sequencing were used. The homology searches were performed using BLAST (https://blast.ncbi.nlm.nih.gov/Blast.cgi). To align the sequences, the CLUSTAL Omega (http://www.ebi.ac.uk/Tools/msa/clustalo/) software was used. In addition, the ENSEMBL Variant Effect Predictor (VEP) was used to predict the possible impact of an amino acid substitution. Locations of SNPs were identified based on genome version of Ovis aries Oar_v3.1. Four SNPs related to *LEPR* gene were selected for genotyping the whole population: one in exon 4 (rs411478947) and 3 in exon 20 (rs412929474, rs428867159, and rs405459906). These SNPs were genotyped by Kompetitive allele specific PCR (KASP, LGC, Biotools, Spain) following the manufacter's instructions.

A total of 3200 ewes were genotyped using KASP technology using the panel of 192 SNPs that included 153 SNPs for parentage assignment and 39 functional SNPs. The functional SNPs are located in genes that could be related to prolificacy (*BMP15* and *GDF9*), seasonality (*MTNR1A*, *ANNAT* and *NPSR1*), AFL (*KISS1*, *KISS1R*, *LEPR*, *IGFR1*), and others (*GHR*, *PRNP*, *TMEM154, SPTAN1*). The genotypes of the population of 351 ewes with phenotypic data for AFL were used. Also, the ENSEMBL Variant Effect Predictor (VEP) was used to predict the possible impact of an amino acid substitution. Locations of SNPs were identified based on genome version of Ovis aries Oar_v3.1.

3. Statistical analysis

The Hardy–Weinberg equilibrium exact test values, observed and expected heterozygosities and minor allele frequency (MAF) for each SNP were estimated using PLINK 1.9 software (Purcell *et al*., 2007).

SNP association studies: The association between *LEPR* polymorphisms and the reproductive seasonality traits (TDA, P4CM, and OCM) were performed by fitting a Linear Mixed Model using the MIXED procedure of SAS statistical package. The model included SNPs genotype (S), age (mature and young ewe) (A), and the interaction of age × genotype of the SNPs (A × S), as fixed effects; live weight (LW) and body condition score (BCS) as covariates; and the animal (An) and the residual (e) as random effects. Homogeneous variance for the residual (e ~N (0, ! 2)) was fited. To test differences between genotypes, the least square means (LSMEANS) for each pairwise comparison were estimated. Bonferroni correction was applied to take into account for multiple tests. All SNPs were independently analyzed with the same statistical model.

Haplotype association studies: The gametic linkage disequilibrium (LD) among SNPs (D' and r2) within the *LEPR* was calculated and visualized using the program Haploview v4.2 (Barrett *et al*., 2005). The SNPs rs411478947, rs412929474, rs428867159, and rs405459906 were phased with PLINK1.9 using the expectation–maximisation (E-M) algorithm to assign individual haplotypes. Diplotypes with a posterior probability higher than 0.7 were considered.

Associations between the haplotypes and reproductive seasonality traits were performed using the MIXED procedure of SAS. The model fitted was similar to that used for the SNP association studies, but including the haplotype (H) effect and the interaction age × haplotype (A × H). Haplotypes for each individual were codified as 0, 1 or 2 indicating the copies number of each haplotype. Only haplotypes with a frequency greater or equal than 1% were considered. To test differences between haplotypes, the least square means (LSMEANS) for each pairwise comparison were estimated. Bonferroni correction was applied to take into account for multiple comparisons.

The association analysis was performed with the GCTA software (Yang *et al*., 2011) taking into account the 192 SNPs. Bonferroni correction was applied to take into account for multiple tests.

III – Results and discussion

For the *LEPR*, the entire exon 4 (330 bp) and almost the complete sequence of exon 20 (909 bp: total coding region [828 pb] + partial 3'UTR [81 pb]) were sequenced. Sequences revealed 11 polymorphisms: 3 and 8 SNPs in exons 4 and 20, respectively. All SNPs were in Hardy-Weinberg equilibrium. In exon 4, two synonymous (rs159694506 and rs159694508) and one non-synonymous (rs411478947) polymorphisms were detected. The non-conservative change of an Arginine to Cysteine (Arg62Cys) (rs411478947) was predicted as tolerated but with a low SIFT value of 0.05 by VEP software. In exon 20, five synonymous (rs403654953, rs426037269, rs415715948, rs414501727 and rs427778198) and three non-synonymous (rs412929474, rs428867159 and rs405459906) polymorphisms were detected. SNPs association analysis showed that non-synonymous SNPs in exon 20 were associated to reproductive seasonality traits. The interaction between the SNP and age affected the TDA (P=0.0004), P4CM (P=0.0005) and OMC (P=0.02) traits for SNP rs412929474, showing different effects in mature and young ewes. The SNP rs405459906 was also significant for the interaction SNP x age (P=0.04). After Bonferroni correction only the TDA phenotype differed among genotypes in young ewes (SNP x age was significant), finding significant differences between GG and AG genotypes (P=0.027). Haplotype association studies confirmed the significant SNP x age interactions (Table 1). In this sense, TDA phenotype differed among haplotypes (P<0.05) at young and adult ewes for h1 haplotype, finding significant differences between 0

and 1 copies (P<0.05). However, animals with no copies of h1 had lower TDA value than those with one copy in mature ewes, while in young ewes, animals with no copies of h1 had higher TDA value than those with one copy. This result could indicate either different behaviour depending on age or that this haplotype is in linkage disequilibrium with other SNPs not detected in this study. The haplotypes h2 and h4 were also associated with OMC trait considering the whole population.

Table 1. Type III test for the haplotype and haplotype x age effects of block 5 on the *LEPR* gene using the seasonality phenotype data from Rasa Aragonesa ewes. The least square means and standard errors for the haplotype effect on the *LEPR* gene are also shown. Only significant haplotypes after Bonferroni correction are shown. Different letters indicate significant differences: a, b: P<0.05. SNP Block: rs411478947, rs412929474, rs428867159, and rs405459906

			Haplotype effect[1]				
Trait	**Haplotype**	**Freq.**	**P-value**	**age**	**0 copies**	**1 copy**	**2 copies**
OMC	h2 (GGTG)	0.08	0.0081	total	0.54+0.02a	0.44+0.05b	0.26+0.14ab
OMC	h4 (GGCA)	0.75	0.0067	total	0.40+0.05a	0.53+0.02b	0.56+0.02b
			Haplotype x age effect[1]				
TDA	h1 (GATG)	0.11	<0.0001	mature	55.01+5.18a	85.81+9.07b	88.36+24.97ab
				young	80.30+6.91a	30.03+12.66b	43.98+118.62ab
OMC	h1 (GATG)	0.11	0.0007	mature	0.57+0.02	0.46+0.04	0.41+0.11
				young	0.48+0.03a	0.66+0.06b	0.44+0.20ab

[1] 0 copies: LSMEANS and SE for 0 copies of the haplotype; 1 copy LSMEANS and SE for one copy of the haplotype; and 2 copies: LSMEANS and SE for 2 copies of the haplotype.

These SNPs are included in the SNP panel and will be used for validation studies of the effects found for the SNPs.

Secondly, we tried to validate some putative functional causal SNPs using the SNP panel as a proof of concept. Association studies using GCTA software showed 16 SNPs associated to AFL trait ($p_{nominal} < 0.05$). These SNPs were located in different genes *BMP15*, *KISS1R*, *MTNR1A*, *SPTAN1*, *FA2H*, *TMEM154*, *MTUS1* genes. However, at the genome level ($p_{Bonferroni} < 0.05$) only the SNP rs421419167 (*BMP15*/*FecX*^{R} allele) was significantly associated to AFL. Associations at genome-wise suggestive significance ($p_{suggestive} \leq 1/n$) were found for three SNPs: rs421419167, rs398938610 and rs412567923 located in *BMP15* (*FecX*^{R} allele), *KISS1R* and *SPTAN1* genes, respectively. The *FecX*^{R} allele causes increased prolificacy in heterozygous and sterility in homozygous ewes. The SNP rs398938610 is a non-conservative mutation (p. C309F) located in *KISS1R* gene. This mutation was predicted as tolerated but with a low SIFT value (0.06) by VEP software. Kisspetin and its receptor *(KISS1R)* form a system that regulate the release of GnRH that modulates the release of gonadotropins from the pituitary. *KISS1/KISS1R* system seems to be important for reproductive physiology aspects, ranging from the initiation of puberty to the induction of ovulation. These results have to be validated in a bigger population.

The results provide an additional resource of potential genetic markers for breeding programs considering the size of the effects found and the relative high frequency of some of the favourable alleles in Rasa Aragonesa animals.

IV – Conclusion

In this work, we confirmed the usefulness of a SNP panel composed by 153 SNPs selected for parentage assignment, and 39 functional SNPs related to prolificacy, seasonality, scrapie resistance, and others. We have validated some SNPs associated to different traits in other studies (*BMP15*/*FecX*^{R} allele, *LEPR*) and putative functional causal SNPs (*KISS1R* and *SPTAN1)*. Fur-

thermore, we have assessed the involvement of the *LEPR* gene in reproductive seasonality in ruminants, including some of the *LEPR* SNPs in the SNP custom panel. These polymorphisms could be useful for the breeding program as genetic markers to identify less seasonal or more prolific animals, and to design adequate decisions about its management in the selection program.

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Investigating whole genome selection signatures in local Moroccan sheep

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Abstract. Sheep farming plays a key role in Moroccan agriculture and is one of the main sources of meat in the country. The main purpose of this study is to characterize diversity and demographic history as well as intra and inter-population selection signatures in the main sheep breeds raised in Morocco using their entire genomes. These local sheep breeds are characterized by a high genetic diversity and thus by a high adaptive potential. Therefore, they represent a valuable genetic resource for the conservation of the sheep species on a worldwide scale. The complete genome data from 87 individuals representing five predominant local sheep breeds in Morocco were used to infer demographic history, which has made it possible to estimate the evolution of the effective population size over time. Two methods were used to investigate selection signatures: one to detect putative regions under selection within each of these breeds and the second to detect selection signatures that differentiate the breeds one from the other. We identified several hundreds of regions/genes under selection from the studied breeds. We highlighted several biological processes involved in local adaptation as well as those linked to zootechnical performances characterizing each breed. Findings of this study increased our understanding on how genetic diversity is distributed in local breeds.

Keywords. Sheep – Whole genome sequences – Selection signatures – Local breeds.

Résumé. *L'élevage ovin joue un rôle clé dans l'agriculture marocaine et constitue l'une des principales sources de viande dans le pays. Le but principal de cette étude est de caractériser la diversité et l'histoire démographique ainsi que les signatures de sélection intra et inter population dans les principales races ovines élevées au Maroc en utilisant leurs données de génomes entiers. Ces races ovines locales se caractérisent par une grande diversité génétique et donc par un potentiel d'adaptation élevé. Par conséquent, ils représentent une ressource génétique précieuse pour la conservation des espèces de moutons à l'échelle mondiale. Les données complètes du génome de 87 individus représentant cinq races ovines locales prédominantes au Maroc ont été utilisées pour déduire l'historique démographique, ce qui a permis d'estimer l'évolution de la taille efficace de la population au fil du temps. Deux méthodes ont été utilisées pour étudier les signatures de sélection : une pour détecter les régions présumées sous sélection dans chacune de ces races et la seconde pour détecter des signatures de sélection différenciant les races les unes des autres. Nous avons identifié plusieurs centaines de régions / gènes sous sélection parmi les races étudiées. Nous avons mis en évidence plusieurs processus biologiques impliqués dans l'adaptation locale ainsi que ceux liés aux performances zootechniques caractérisant chaque race. Les résultats de cette étude ont permis de mieux comprendre la répartition de la diversité génétique dans les races locales.*

Mots-clés. *Moutons – Séquences de génomes complets – Signatures de sélection – Races locales.*

I – Introduction

Sheep farming plays a key role in Moroccan agriculture and is one of the main sources of meat in the country. It is mainly based on the breeding of indigenous breeds (e.g. Timahdite, Sardi, Dman, BeniGuil, etc.) well adapted to the specific and contrasting environmental conditions that prevail in their cradles as reported in the sheep plan (MARA, 1980). In the context of environmental change,

the improvement and conservation of this species are major challenges for the sustainable grant to the growing need for meat products both at national and international level. This conservation requires a perfect knowledge of their genetic heritage. The technological advances of the last decade have allowed access to the majority of the genome diversity of individuals and previous studies have shown via these technologies the importance of genome-environment relationships in Moroccan sheep (Benjelloun, 2015). However, the genomic specificities and genomic bases of the specific traits of local breeds are not known. In this context, the present work aims to determine the intra and inter-population selection signatures in five sheep breeds widely raised in Morocco using their complete genomic data. It identified the genomic regions/genes involved in local adaptation and those related to zootechnical performances characterizing each breed.

II – Material et methods

This study focused on the analysis of data from four officially identified sheep breeds (Timahdite, Sardi, Dman and BeniGuil) and a breed that is widely raised in the Oriental region and which is considered a priori as foreign: Ouled Jellal. The complete genomes of 87 sheep including 16 Timahdite, 27 Sardi, 30 Dman, 6 BeniGuil and 8 Ouled Jellal were analysed. The genotyped animals were sampled to represent the ecological and geographical diversity of each breeding area of the studied breed. Genomic data were produced at 12x coverage and then mapped on the reference genome OARv3.1 (Jiang *et al.,* 2014) and then processed using the pipeline described by Benjelloun (2015).

1. Inferring demographic history

The number of exclusive variants was calculated using Vcftools program (Danececk *et al*., 2011). The effective population size (*Ne*) of the studied breeds was inferred using popsizeABC algorithm (Boitard *et al*., 2016). Similarly, the demographic history was inferred by the same program, which made it possible to estimate the evolution of the effective population size over time from genomic data. For a basis of comparison, we have inferred the demographic history of a group of 13 wild sheep (*O. orientalis*) previously sampled in Iran and a group of 20 sheep representing 20 cosmopolitan breeds sampled in Eurasia, Africa and Australia (Benjelloun, 2015; Alberto *et al*., 2018).

2. Investigating intra-population selection signatures using freqHMM

Following the results obtained on the demographic history, which made it possible to understand the demography of these breeds, a genomic scan was carried out using freqHMM software (Boitard *et al*., 2012) to identify regions potentially under selection within each breed. This is a program that can detect variants under intra-population selection. The input files included all non-rare SNP variants identified in the five breeds (31,442,046 SNPs having MAFQ>=0.05), considering as ancestral alleles the homozygous alleles of the reference goat for the corresponding loci. This allowed to calculate the number of derived and ancestral alleles for each SNP. Then, the freqHMM analysis was done using the calibrated and adapted parameters for each breed.

3. Investigating inter-population selection signatures using hapFLK

The second part of the analyses consists of looking for breeding signatures differentiating breeds by FLK methods (Bonhomme *et al*., 2010) and hapFLK (Fariello *et al*., 2013) while considering the group of 13 Asiatic mouflons as outgroup. Both tests aim to identify typical differentiation regions between populations while considering their structures. The FLK test infers the Kinship matrix and Reynolds distances. The hapFLK algorithm has been applied to genomic data while considering sliding windows of 10Mb chromosomal segments with 1Mb overlaps.

III – Results and discussion

1. Demographic history results

The intra-breed diversity state shows very high numbers of exclusive variants within each breed and we note that the two Dman (1.8 million) and Sardi (1.6 million) breeds have the most exclusive variants (Table 1). These numbers of exclusive variants are not correlated with the effective population size of each breed (Table 1). The highest effective size is recorded by the Timahdite breed (Ne ~ 47,000), while other breeds have close effective sizes. The values obtained for these local breeds are substantially higher than those of wild sheep populations at the centre of domestication (Ne = 2,016). Moreover, as expected, cosmopolitan races (even when grouped) are marked by a very low effective size (Ne = 285), despite being present in very large numbers worldwide. This shows the threat of large-scale distribution of these breeds and their replacement of local breeds around the world. In addition, the effective sizes of the local breeds studied are very high compared to what is reported in the literature for sheep breeds (e.g. Maiwashe and Blackburn, 2004, Tapio *et al.*, 2005). This illustrates the exceptional adaptive potential of these local breeds and the opportunity to further intensify the reasoned programs of their breeding while maintaining this richness.

Table 1. Demographic characteristics of the studied populations

Breed	Beni Guil	Dman	Ouled Jellal	Sardi	Timahdite	Asian Mouflons	20 cosmopolitan breeds
No. of exclusive variants	341,296	1,783,651	460,461	1,621,728	934,212	–	–
Effective population size (Ne)	30,921	29,789	25,811	28,523	47,097	2,016	285

2. Intra population selection signatures in local sheep breeds

A whole analysis pipeline was set up to calibrate the research programs of the selection signatures according to the demographic histories that the studied breeds had experienced. Once these programs were calibrated, we were able to identify a large number of variants and genes selected in each one of the studied breeds. From a total of 31,442,046 SNPs analysed, 43,616 variants associated with 115 genes in the Sardi breed, 34,909 SNPs associated with 96 genes were identified under selection in Timahdite, 56,218 variants associated with 153 genes in Dman, 54,845 associated with 127 genes in the Beni Guil breed and 53,346 variants associated with 139 genes in Ouled Jellal, were identified under selection. Table 2 illustrates the number of SNPs variants and associated genes that are commonly identified under selection between each couple of breeds. We note that the three breeds Timahdite, Sardi and Dman; share more SNPs/genes under selection between each other than with the other two breeds. More investigation would elucidate the reasons and the biological processes associated.

Table 2. Number of selected SNPs (above the diagonal) and selected genes (below the diagonal) common to each two sheep breeds

Breed	Beni Guil	Dman	Ouled Jellal	Sardi	Timahdite
Beni Guil	–	8.180	5.307	6.311	5.880
Dman	36	–	5.795	14.568	9.436
Ouled Jellal	30	32	–	8.238	6.846
Sardi	30	70	36	–	9.708
Timahdite	25	60	33	45	–

The number of variants identified under selection commonly in all studied breeds is 219. These variants are associated with 4 genes (Fig. 1): *HMGA2*, *RCOR1*, *SBF2* and *U6*. These genes are generally involved in the cellular functioning of sheep. The genes identified in common by considering different combinations of breeds and also the signatures associated exclusively in a given breed (Fig. 1) will shed light on biological processes underlying both adaptive and zootechnical traits selected in each breed.

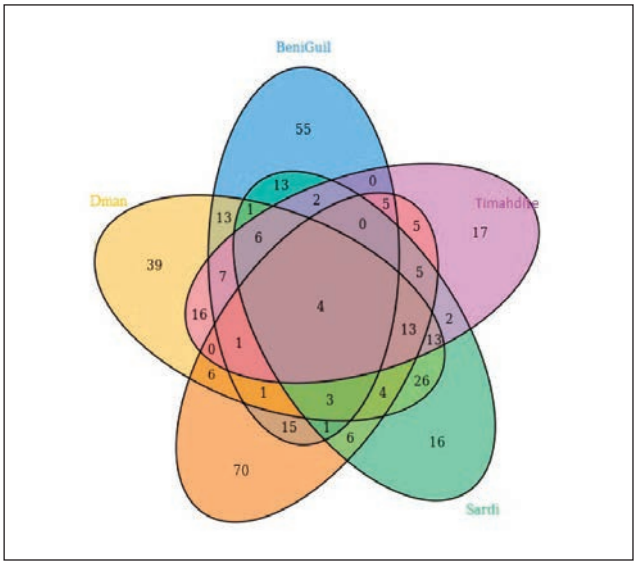

Fig. 1. Venn diagram ilustrating the number of genes selected commonly in flve local sheep breeds and those exclusively selected in each breed.

3. Inter population selection signatures in local sheep breeds

The hapFLK scores were subjected to Bonferroni correction to determine the selection threshold. The analysis process identified 3,536 variants under selection that differentiate the five local breeds. The main selective sweeps identified are associated with the genes *RXFP2, FANCA-201, SPIRE2, TCF25 and MC1R-201*. (Fig. 2). The association between all the SNPs/genes identified and the breeds under consideration would highlight the selected biological processes within each breed.

IV – Conclusion

The results obtained at this stage identified several regions and genes selected in the studied breeds. This would allow understanding the mechanisms differentiating the main sheep breeds in Morocco and their genomic traceability. Considerable work is planned to identify the associated biological processes. Outlier genomic variants identified here will be ranked according to their importance in the context of climate changes and some of them would be very precious when designing selection programs based on adapted genotyping tools.

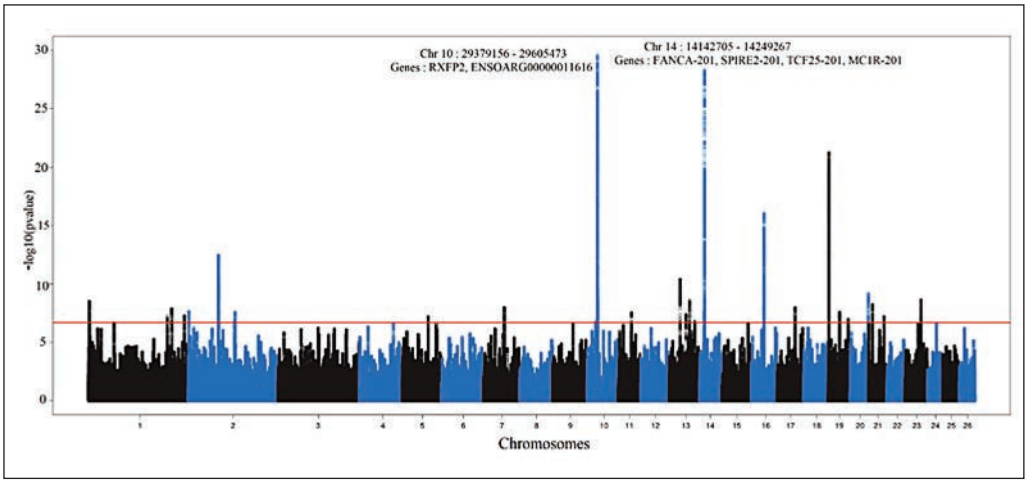

Fig. 2. Manhattan plot depicting hapFLK scores in five Moroccan sheeps along their genome. Each point represents a SNP. The horizontal red line represents the 5% Bonferroni threshold of significance.

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Assessment of different extenders for the cryopreservation of Moroccan Beni Arouss buck semen with no sperm washing

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Abstract. This study aimed at investigating the effects of two commercial extenders and skimmed milk extender on the quality of cryopreserved buck semen without washing. Ejaculates were collected from four Beni Arouss bucks using an artificial vagina, pooled and split into equal parts in three tubes. Tubes were diluted in parallel at 37°C with Optixcell® semen extender already containing glycerol, INRA96® semen extender and skim milk-based extender. After cooling to 4°C, glycerol (7%) was added to samples diluted with INRA96® and skimmed milk extenders and all samples were equilibrated, cryopreserved and stored in liquid nitrogen. CASA motion parameters, viability and normal morphology of sperm were assessed after dilution, equilibration and freeze–thawing. The cryopreservation process had a significant effect on semen quality. All parameters decrease over time of the storage process ($P < 0.001$). Optixcell® extender provided more effective preservation after freeze-thawing followed by skimmed milk extender and then INRA96® extender ($P < 0.05$) of progressive motility (47%, 35% and 16%, respectively), velocity parameters (RAPID: 48%, 33% and 14% respectively and VCL: 100 µm/s, 83 µm/s, 71 µm/s and VSL: 58 µm/s, 56 µm/s and 45 µm/s, respectively) and viability (41%, 32% and 16%, respectively). No significant differences were observed between extenders regarding the normal morphology ($P > 0.05$). It was concluded that Optixcell® extender allowed better cryoprotection to Beni Arouss buck spermatozoa as showed by semen quality parameters.

Keywords. Extender – Buck semen – Cryopreservation – Semen quality.

Evaluation de différents dilueurs pour la congélation de la semence du bouc Beni Arouss sans lavage préalable de la semence

Résumé. *Cette étude a pour objectif d'évaluer l'effet de deux dilueurs commerciaux et d'un dilueur conventionnel à base du lait écrémé sur la conservation en congelé de la semence du bouc sans lavage préalable de la semence. Les éjaculats prélevés à l'aide d'un vagin artificiel de quatre boucs Beni Arouss ont été mélangés et repartis en portions égales dans trois tubes. Ces derniers ont été dilués en parallèle, à 37°C, avec un dilueur commercial qui contient du glycérol (Optixcell®), un deuxième dilueur commercial (INRA96®) et un dilueur à base de lait écrémé. Après refroidissement progressif à 4°C, le glycérol (7%) a été ajouté dans les échantillons dilués avec l'INRA96® et le lait écrémé. L'ensemble des échantillons ont été soumis à une équilibration avant d'être congelés et conservés en azote liquide. Les paramètres de motilité générés par le CASA, la viabilité et la morphologie normale des spermatozoïdes ont été évalués après dilution, après équilibration et après congélation-décongélation. D'après les résultats, la congélation a un effet significatif sur la qualité de la semence. L'ensemble des paramètres diminue au cours du processus de la congélation ($P < 0,001$). Optixcell® a permet une conservation plus efficace de la qualité de la semence après congélation-décongélation suivi de lait écrémé, puis de l'INRA96® ($P <0,05$). Les pourcentages de la motilité progressive ont été respectivement 47%, 35% et 16% pour les trois dilueurs. Des pourcentages respectifs de 48%, 33% et 14% ont été enregistrés pour RAPID, 100 µm/s, 83 µm/s et 71 µm/s pour VCL, 58 µm/s, 56 µm/s et 45 µm/s pour VSL et 41%, 32% et 16%, pour la viabilité. Aucun effet du dilueur sur la morphologie normale n'a été enregistré ($P> 0,05$). En conclusion, Optixcell® a permet une meilleure conservation en congelé de la semence du bouc Beni Arouss.*

Mots-clés. *Dilueur – Sperme du bouc – Congélation – Qualité de la semence.*

I – Introduction

In the North of Morocco, Beni Arouss goat farming contributes approximately to 70% of rural population incomes (Chentouf *et al*., 2011). In order to preserve this local goat breed and improve farm productivity, a genetic improvement program is implemented by a professional organization (ANOC) and supported by the Ministry of Agriculture. Artificial insemination is of crucial importance to identify and disseminate the genetic progress of this breed. The development of an optimal and easy protocol for semen cryopreservation is necessary to accompany this genetic improvement program. In goats, sperm washing step is largely recommended to improve the quality of frozen-thawed buck semen when diluents containing egg yolk or skimmed milk are used (Leboeuf *et al*., 2000; Purdy, 2006). However, this step is a time consuming and can be responsible of sperm damaging or lost (Miro *et al*., 2009). Still, many studies report that removing the seminal plasma when freezing buck semen is not necessary (Leboeuf *et al*., 2000; Azeredo *et al*., 2001; Purdy, 2006). The aim of the present research was to study the effect of two commercial extenders (Optixcell® and INRA96®) and skimmed milk extender on the quality of cryopreserved buck semen without washing.

II – Material and methods

1. Animals and semen collection

Four Beni Arouss bucks aged between 3 and 7 years and weighted between 40 and 52 kg were used in this study. They were maintained at the experimental station of INRA, regional center of Tangier (35°N of latitude) under natural conditions of photoperiod and optimum feeding conditions. Semen was collected during breeding season using an artificial vagina. A total of 24 ejaculates were collected in 6 replicates throughout the study period. After collection, semen was placed in a water bath at 37 °C and evaluated for volume, colour, mass motility and sperm concentration. Only ejaculates between 0.6 and 2 ml of volume with a concentration greater than 2 x 10^9 spermatozoa/ml and having a mass motility higher than 4 were selected and pooled for cryopreservation.

2. Semen cryopreservation

Immediately after collection and pooling, ejaculates were divided into equal parts in three tubes. Tubes were diluted in parallel, by two steps method. The first fraction added at 37°C of Optixcell® semen extender already containing glycerol, INRA96® semen extender and skim milk-based extender. After cooling to 4°C, a second fraction containing glycerol (14%) was added to samples diluted with INRA96® and skimmed milk extenders in order to achieve a final concentration of 400 x 10^6 spermatozoa/ml and 7% glycerol level in the final volume. The diluted semen was then equilibrated at 4°C for 2 hours. After equilibration, the semen was aspirated into 0.25 ml French straws and sealed with polyvinyl powder. The straws were cooled at a rate of 7 °C/min from 4 to –50 °C and 25 °C/min from –50 to –150 °C in a programmable freezer (Micro-Digitcool®, IMV, France), then plunged into liquid nitrogen for storage. Thawing was carried out in a water bath at 37 °C for 30 s.

3. Semen evaluation after dilution, equilibration and freeze-thawing

The sperm motion and normal morphology parameters were assessed immediately after dilution, equilibration and freeze-thawing using a computer-assisted sperm analysis system (ISAS®, Proiser R + D SL, Spain) using the procedures published by El kadili *et al*. (2019). The following motility parameters were assessed: percentage of progressive motile spermatozoa (PM, %), curvilinear velocity (VCL, µm/s), straight line velocity (VSL, µm/s) and rapid spermatozoa (RAPID, %). The viability of the sperm was evaluated following eosin–nigrosin staining (Evans and Maxwell, 1987).

4. Statistical analysis

Data were analysed using the GLM procedure of SAS 9.0. An ANOVA model for repeated measures was used for each parameter of sperm quality. The model included the fixed effects of extender and time of analyse. Differences between mean values were analysed by the LSD test. Data were presented as mean ± SD, and the level of significance was set at $P < 0.05$.

III – Results and discussion

Table 1 summarizes results obtained in this experiment. As expected, all parameters were reduced after semen freeze-thawing ($P < 0.001$). Cryopreservation that included dilution, cooling, equilibration, freezing and thawing induces detrimental effects in sperm cells, resulting in a reduction of motility, membrane integrity and fertilizing ability. Similar results were reported by Watson (2000) and Purdy (2006).

Table 1. Effect of different extenders on semen quality of post dilution, equilibration and freeze-thawing semen in Moroccan Beni Arouss bucks (mean ± SD)

Semen parameters	Extenders		
	Optixcell	INRA96	Skimmed milk
Progressive motility (%)			
After dilution	70.82±4.12a	71.95±6.16a	71.08±8.74a
After equilibration	67.28 ±12.28a	64.95±13.42a	62.83±11.64a
After Freeze-thawing	47.13±13.32bx	15.82±11.26by	34.92±12.84bx
RAPID (%)			
After dilution	85.28±7.36a	86.03±11.65a	80.67±14.92a
After equilibration	76.23±15.72a	67.60±16.02b	66.86±12.64a
After Freeze-thawing	48.50±9.32bx	13.95±10.72cy	32.75±16.15bx
VCL (µm/s)			
After dilution	124.81±20.25ax	125.61±14.88ax	106.56±16.19ay
After equilibration	118.81±8.97a	121.06±16.72a	103.96±16.33a
After Freeze-thawing	99.76±19.32bx	70.78±15.97by	83.38±20.41bxy
VSL (µm/s)			
After dilution	53.28±13.42	67.63±13.17b	61.81±10.80
After equilibration	56.08±9.66y	74.35±15.11ax	64.78±20.71y
After Freeze-thawing	58.55±15.16x	45.01±16.51cy	55.95±21.32xy
Viability (%)			
After dilution	70.75±6.54a	75.92±11.83a	72.68±9.96a
After equilibration	68.42±11.12a	65.83±13.85a	67.67±10.76a
After Freeze-thawing	40.67±8.61bx	15.58±8.28by	32.08±11.38bx
Normal sperm (%)			
After dilution	80.58±3.10	83.50±3.21a	80.33±3.30
After equilibration	79.33±3.61	78.00±3.85a	78.75±2.42
After Freeze-thawing	76.83±3.87	71.83±4.67b	77.58±6.84

a,b Means with different superscripts in the same column indicate significant difference for a parameter among times of evaluation($P<0.001$).

x,y Means with different superscripts in the same row indicate significant difference among treatment groups ($P<0.05$).

Significant differences were found between semen extenders in term of sperm quality. Most of the freeze-thawing sperm motility and viability parameters were significantly higher in samples diluted in Optixcell® extender followed by those diluted in skimmed milk extender and then those diluted in INRA96® extender. Whereas, there was no effect of extender on the percentage of normal sperm ($P > 0.05$). Optixcell® is a liposomes-based extender that demonstrated a better result than INRA96® extender supplemented with a purified fraction of caseins (native phosphocaseinate) in our experiment. The variations in findings using liposomes-based extender is might be due to the difference in protective effect of liposomes or to glycerol concentration which is unknown in Optixcell®. Regarding semen motility, viability and normal morphology a good semen quality was obtained without sperm washing, using skimmed milk extender. This implied that semen without washing could be extended in this extender for cryopreservation in Beni Arouss buck.

IV – Conclusions

In conclusion, results of the present study suggest that Optixcell® extender allowed better cryoprotection to Beni Arouss buck spermatozoa as showed by semen quality parameters. During the breeding season, skimmed milk can be used as a conventional and economic extender for cryopreservation of Beni Arouss buck semen without sperm washing.

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SheepToShip LIFE: Looking for an eco-sustainable sheep supply chain. Preliminary results on GHG emission of dairy sheep farms

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Abstract. SheepToShip LIFE is an EU project launched in 2016 to develop an intervention model for the eco-innovation of the Sardinian sheep-dairy supply chain, able to reduce greenhouse gas (GHG) emissions by 20% over the next 10 years through improved efficiency of production systems. This work shows the preliminary results of the Life Cycle Assessment (LCA) conducted in four case study farms, characterized by different production and management systems. The environmental performances of each farm are expressed in terms of Carbon Footprint (CF) per unit of product (fat and protein corrected milk, FPCM) and unit of area (ha of utilized agricultural area, UAA), with the additional goal of identifying the main processes that contributed to the total CF (hotspots). Farms were surveyed to gather primary data for a "from cradle to farm gate" LCA study. The average CF (CO_2-eq kg $FPCM^{-1}$) of the four farms was equal to about 3.4 kg CO_2-eq, ranging from 2.6 to 4.2. Cropland-based farms with a higher Dairy Efficiency (DE – expressed as kg FPCM kg DMI^{-1}) showed lower values of CF, as compared with pastureland-based farms. Contrasting results were obtained when one ha of UAA was used as functional unit. Enteric CH_4 emission contributed on average about 57% of total CF, representing the main environmental hotspot.

Keywords. Carbon Footprint – Dairy efficiency – Sheep system – Environmental hotspot.

Sheep ToShip LIFE : À la recherche d'une chaîne d'approvisionnement ovine éco-durable. Résultats préliminaires sur les émissions de GES des exploitations ovines laitières

Résume. *SheepToShip LIFE est un projet européen lancé en 2016 pour développer un modèle d'intervention pour l'éco-innovation de la filière ovine-laiterie sarde, capable de réduire les émissions de gaz à effet de serre (GES) de 20% au cours des 10 prochaines années grâce à une meilleure efficience des systèmes de production. Ce travail présente les résultats préliminaires de l'analyse du cycle de vie (ACV) réalisée dans quatre fermes d'étude de cas, caractérisées par différents systèmes de production et de gestion. Les performances environnementales de chaque exploitation sont exprimées en termes d'empreinte carbone (EC) par unité de produit (lait corrigé en matières grasses et en protéines, LCMP) et par unité de surface (ha de surface agricole utilisée, SAU), avec pour objectif supplémentaire d'identifier les principaux processus qui contribuent à l'EC totale (points chauds). Les exploitations agricoles ont été interrogées afin de recueillir des données primaires pour une étude ACV "du berceau à la porte de la ferme". La EC moyenne (CO_2-eq kg $LCMP^{-1}$) des quatre exploitations était égale à environ 3,4 kg CO_2-eq, allant de 2,6 à 4,2. Les exploitations basées sur des cultures et présentant un rendement laitier (DE - exprimé en kg LCMP kg DMI^{-1}) plus élevé ont présenté des valeurs de EC inférieures à celles des exploitations basées sur des pâturages. Des résultats contrastés ont été obtenus lorsqu'un ha de SAU a été utilisé comme unité fonctionnelle. Les émissions de CH4 entériques ont contribué en moyenne à environ 57% de la EC totale, représentant le principal point chaud environnemental.*

Mots-clés. *Empreinte carbone – Efficacité laitière – Système ovin – Point chaud environnemental.*

I – Introduction

Agriculture largely contributes to global warming and ruminants are major responsible to greenhouse gas (GHG) emissions in this sector (Gerber *et al*., 2013). Small ruminants in the world are about 56% of global ruminant domestic population (FAO, 2016a). Sheep production systems contribute to global GHG emissions with around 254 Mt CO_2-eq (Opio *et al*., 2013), with 67.1 Mt CO_2-eq attributed to the sheep milk production (Hristov *et al*., 2013). However, most of Carbon Footprint (CF) studies were carried out on dairy cattle, whereas few studies were based on dairy sheep (Opio *et al*., 2013; Marino *et al*., 2016, Vagnoni and Franca, 2018).

Italy is one of the first world sheep milk producers and sheep cheese exporters. In particular, about 25% of total EU-27 sheep milk is produced in Sardinia (Italy) (Rural Development Programme of Sardinia, 2014-2020). In this region, characterized by typical Mediterranean climate, the variable farming systems determine different forage systems (Porqueddu *et al*., 2017), depending on the pedo-climatic context. Usually, farms with extensive management have forage systems based on natural pastures, while annual forage crops characterize the farms with more intensive management (Vagnoni *et al*., 2015).

SheepToShip LIFE is an EU project launched in 2016 to develop an intervention model for the eco-innovation of the Sardinian sheep-dairy supply chain, able to reduce GHG emissions by 20% over the next 10 years through improved efficiency of production systems. Twenty farms located in contrasting pedo-climatic zones were selected to conduct a Life Cycle Assessment (LCA) study. This work shows the preliminary results of the LCA performed in four case study farms, characterized by different production and management systems. The environmental performances of each farm are expressed in terms of CF per unit of product (CO_2-eq per kg of fat and protein corrected milk, FPCM) and per unit of area (ha of utilized agricultural area, UAA) with the additional goal of identifying the main processes that contributed to the total GHG emissions (hotspots).

II – Materials and methods

The study was carried out from October 2016 to September 2017 on four dairy sheep farms located in different area of Sardinia. Farms were surveyed to gather primary data for a “from cradle to farm gate” LCA study. Main information on the geographical location, crop system, milk production, herd size and sheep diet of each farms are reported in Table 1. Using a model based on IPCC (2006) Tier 2 with updated values for CH_4 and N_2O characterization factors, farm data were analyzed to estimate CF values. One kg of fat and protein correct milk (FPCM) and one ha of utilized agricultural area (UAA) were adopted as function units (FUs). The main processes that contributed to the total CF were also analyzed.

Table 1. Main characteristics of the four different dairy sheep farms

	Unit	Farm 1	Farm 2	Farm 3	Farm 4
Altitude	m a.s.l.	540	464	50	121
Geographical areas	Latitude, pedologic substrate	Centre, granitic	North, alluvial	North, alluvial	South, alluvial
Utilized Agricultural Area (UAA)	ha	79.3	51.8	71.7	182.3
Natural pasture area	% UAA	66.7	49.8	23.7	0.0
Annual forage crops	% UAA	33.3	50.2	76.3	100.0
Heads (number of mature ewes)	N	240	248	375	1312
Stocking rate	head ha^{-1}	3.0	4.8	5.2	7.2
Milk total annual production	kg FPCM	29,692	38,017	72,649	277,577
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	123.7	153.3	193.7	211.6
Concentrate Intake	% on total dry matter intake (DMI)	25	21	29	34
Dairy Efficiency (DE)	kg FPCM kg DMI^{-1}	0.27	0.28	0.36	0.46

III – Results

CF (CO_2-eq kg $FPCM^{-1}$) was equal to 4.2, 3.7, 3.1 and 2.6 in Farm 1, Farm 2, Farm 3 and Farm 4, respectively (Fig. 1a). The total GHG emissions of 1 ha of UAA were 1,581, 2,710, 3,090 and 3,983 kg of CO_2-eq in the same farms, respectively (Fig. 1b). The contribution analysis underlined that enteric CH_4 emissions determined on average about 57.5% ± 1.1 (± standard error) of total CF. Emissions relative to on-farm and off-farm feed production, on-farm manure production and energy use (diesel and electric energy) contributed for about 19.7% ± 0.9, 13.8% ± 0.4 and 9.0% ± 1.4, respectively.

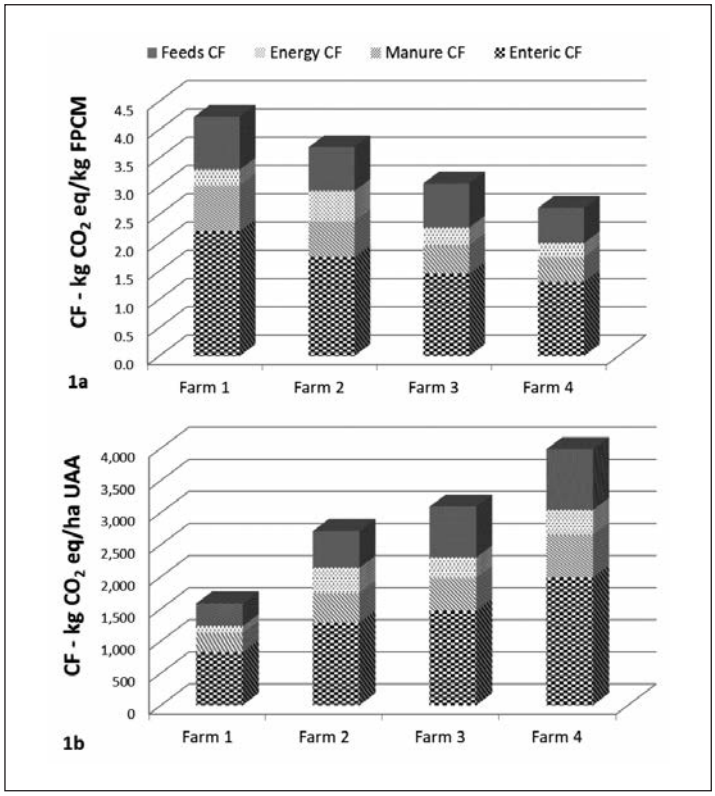

Fig. 1. Carbon Footprint (CF) of the milk produced in the four case study farms, using 1 kg of Fat Protein Corrected Milk (FPCM) (1a) and 1 ha of Utilized Agricultural Area (UAA) (1b) as functional units.

III – Discussion

Different environmental conditions influenced and characterized both structure and management system in the four case study farms. The increase of natural pastures as forage resource was proportionally associated to a reduction of Dairy Efficiency (DE), which, in turn, was the main cause of the CF increase per kg FPCM. CF values appeared strictly linked to animal requirements and production levels. Similar results were observed by other recent studies carried out under Mediterranean conditions, where CF per kg FPCM was lower in intensive farms than extensive ones (Batalla *et al.*, 2015; Vagnoni *et al.*, 2018).

However, when GHG emissions were estimated per ha of UAA, farms showed an opposite trend. This result may be explained by a lower milk production per ha of UAA for farms with lower DE. This outcome confirmed that is advisable to adopt both mass and area-based FUs for CF estimation of livestock products (Salou *et al*., 2017). On the other hand, for a comprehensive assessment of the environmental implications of dairy sheep farming systems, it is strongly recommended to use other impact categories than CF, such as eutrophication, acidification, land use, etc. (PEFCR, 2018). Moreover, an effective estimate of the environmental implications of dairy sheep productions might consider the ecosystem services provided by the sheep farm, soil carbon sequestration from pasture and crops, *in primis* (Batalla *et al*., 2015; FAO, 2016b).

Estimated enteric CH_4 emission based on IPCC 2006 was by far the main environmental hotspot, as observed in other studies carried out on dairy sector (FAOa, 2016; González-García *et al*., 2013; Marino *et al*., 2016; Vagnoni *et al*., 2015). Mitigation strategies based on diet modification seem to be an effective way to improve environmental performances (Rossi *et al*., 2017). However, diet modification in dairy sheep could be different from other ruminants (van Gastelen *et al*., 2019) and specific studies are needed.

IV – Conclusions

Preliminary results indicated that, as expected, CF in the four dairy sheep farms studied was affected by the management and structure of farming system. Cropland-based farms with a higher DE showed lower values of estimated CF per kg FPCM than pastureland-based farm. When GHG emissions were estimated per ha of UAA, CF values showed an opposite trend that can be explained by the lower milk production per ha of UAA observed in farms with lower DE. Enteric CH_4 emissions resulted the main environmental hotspot in all farms, contributing for about 57% to total GHG emissions.

Acknowledgments

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Identification of molecular markers in GDF9gene of Egyptian goat breeds

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Abstract. The aim of this study was to investigate the presence of polymorphism in growth differentiation factor 9 (GDF9) genes and their possible association with litter size in two more prolific goat breeds in Egypt.The does were selected according to their litter size trait, using the pedigree records. Each doe was assembled into two groups: single birth (SB, n = 30) and multiple births (MB, n = 30). In Baladi goat breed, polymorphic restriction pattern indicate presence of one band with 710 bp among all SB does and three bands with 710 and 600 bp and 100 bp for MB does In Zaraibi goats, polymorphic restriction pattern indicate presence of one band with 700bp among all SB does and two bands with 600 bp and 100 bp for MB does. These result showed that presence of polymorphic of GDF9 in Baladi goat and monoomorphic of GDF9 in Zaraibi MB does. The mutations in the GDF9 gene associate with fecundity were identified only in investigated MB Egyptian goat breeds. Alignment of the tested alleles with copracircus GDF9 sequence from gene bank showed transition in multiple births does from CCGAGG to GTTCAT and from TT to AG in regions from 52 to 57 and from 61 to 62, respectively.The study indicates the possibilities of using these markers for selection for high prolificacy in Egyptian goats.

Keywords. GDF9 – Prolificacy – Goat – Fecundity genes – Polymorphism.

Identification de marqueurs moléculaires dans les gènes GDF9 et FSHβ de races de chèvres égyptiennes

Résumé. *L'objectif de cette étude était d'étudier la présence d'un polymorphisme dans le gène du facteur de différenciation de croissance 9 (GDF9) et leur association possible avec la taille de la portée dans deux races de chèvres plus prolifiques en Égypte. Les biches ont été sélectionnées en fonction de leur trait de taille de portée, en utilisant les enregistrements de pedigree. Chaque race a été assemblée en deux groupes: naissance unique (SB, n = 30) et naissances multiples (MB, n = 30). Chez les chèvres Baladi, le schéma de restriction polymorphe indique la présence d'une bande de 710 pb parmi toutes les bés SB et de trois bandes de 710 à 600 pb et 100 pb chez les chèvres B. Chez les chèvres Zaraibi, le schéma de restriction polymorphe indique la présence d'une SB et deux bandes avec 600 pb et 100 pb pour MB. Ces résultats ont montré que la présence de GDF9 polymorphe chez la chèvre Baladi et de GDF9 monomorphe chez Zaraibi MB le fait. Les mutations du gène GDF9 associées à la fécondité ont été identifiées uniquement chez les races de chèvres égyptiennes MB examinées. L'alignement des allèles testés avec la séquence capDFhircus GDF9 d'une banque de gènes a montré une transition lors de naissances multiples de CCGAGG à GTTCAT et de TT à AG dans les régions de 52 à 57 et de 61 à 62, respectivement. L'étude indique les possibilités d'utilisation de ces marqueurs pour la sélection à haute prolificité chez les chèvres égyptiennes.*

Mots-clés. *GDF9 – Prolificacy – Chèvre – Gènes de fécondité – Polymorphisme.*

I – Introduction

Phenotypic evaluation and culling of candidate animals for traits by applying traditional animal breeding are usually costly tasks which require considerable time to be carried out.The identification of polymorphism and DNA markers associated with reproductive traits could be used as marker-assisted selection which lead to genetic improvement to increase litter size and reproduction effi-

ciency (Ghaffari *et al*., 2009).Selection based upon markers could result in increasing accuracy as well as selection response of animals(Ji *et al*., 2003).Therefore, The aim of this study was to investigate the presence of polymorphism in GDF9gene and their possible association with litter size in the Zaraibi and Baladi Egyptian goat breeds

II – Materials and methods

1. Sample Collection and genomic DNA Extraction

Blood samples were collected from the jugular vein of Zaraibi and Baladi herds kept in Sakha experimental station. The station belongs to Animal Production Research Institute, Agriculture Research Center. The both breeds are the more prolific goat breeds in Egypt and the does were assembled into two groups; single birth (SB, n = 30) and multiple births (MB, n = 30).Genomic DNA was extracted from whole blood according the method described by Miller *et al*. (1988).

2. PCR amplification of GDF9 gene

Two pairs of primers were designed to amplify axon 1 and flanking of goat GDF9 gene which corresponded to the Gen Bank accession number AF078545, according to Hanrahan *et al*. (2004). The sequences of the two pairs of primers were as follows:5'-AATTGAACCTAGCCCACCCAC-3' and 5'-AGCCTACATCAACCCATGAGGC-3'. Polymerase chain reactions were carried out in a 25 µL volume containing approximately 12.5 µl Master Mix (OnePCR™), 1 µl of each primer, 2 µl of genomic DNA (50 ng/µl), and 8.5 µl of sterile deionized water.The amplification reaction conditions was carried out using 35 cycles at 94°C for 5 min, followed by 35 cycles of denaturation at 94°C for 1min, and 72 °C for 2 min, and a final extension step at 72 °C for 10 min using thermal cycler 2720 . PCR products were checked by electrophoresis using 1.8% agarose gel in 1× TAE buffer. The products were then purified using the QIAquick Gel Extraction kit no. 28706 and sequenced by automated DNA sequencing reactions.

3. Polymorphism detection and genotyping

Sixty PCR products of partial GDF9 gene (exon 1) were digested using Msp1 restriction enzyme (Germany ER0541) according to the manufacturer's instructions. A final reaction volume of 32 µl contained 10 µl PCR product, 18 µl H2O free of nuclease, 2 µl of 10× buffer, and 2 µl (5 units) of restriction enzyme. The final volume of the mixture was mixed gently and spun down for a few seconds and then incubated for 18 h at 37 °C in water bath and stopped at 65 °C for 10 min. Restriction digestion products were checked by electrophoresis using 3% agarose gel in 1× TAE buffer and staining with ethidium bromide. The 100-bp ladder was used as a molecular size marker.

III – Results and discussion

1. Genotyping of GDF9 gene Using PCR-RFLP Technique

In Baladi goat breed, polymorphic restriction pattern indicate presence of one band with 710 bp among all SB does and three bands with 710 and 600 bp and 100 bp for MB does (Figs. 1 and 2).

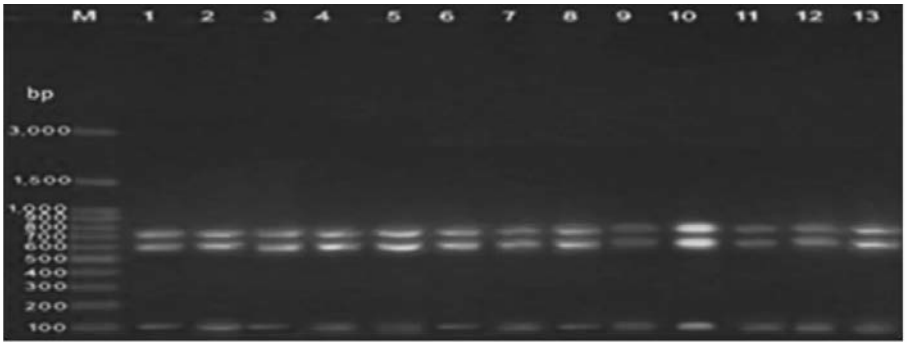

Fig. 1. Lanes (1-13) represents the PCR productsof GDF9 gene of MB Baladi goat breed.

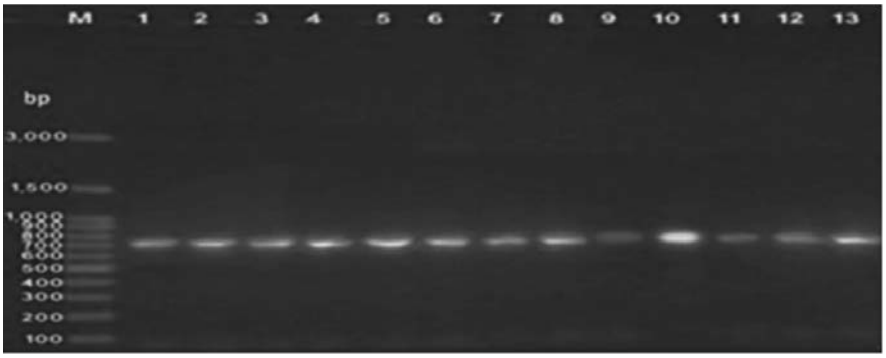

Fig. 2. Lanes (1-13) represents the PCR products of GDF9 gene of SB Baladi goat breed.

In Zaraibi goats, polymorphic restriction pattern indicate presence of one band with 700bp among all SB does and two bands with 600 bp and 100 bp for MB does (Figs. 3 and 4).These result showed that presence of polymorphic of GDF9 in Baladi goat and monomorphic of GDF9 in Zaraibi MB does. The mutations in the GDF9 gene associate with fecundity were identified only in investigated MB Egyptian goat breeds. Mutations in fecundity genes GDF-9 and BMP-15 have important economic values in sheep and goat breeding (Hanrahan *et al*., 2004). Noshahr and Rafat (2014) reported that the presence of one copy of mutant GDF9 gene increase fecundity rate in sheep.

2. Sequence Analysis

Alignment of the tested alleles with Capra hircus GDF9 sequence from gene bank showed transition in multiple births does from CCGAGG to GTTCAT and from TT to AG in regions from 52 to 57 and from 61 to 62, respectively. These nucleotide changes associated with amino acid substitution .Transition from A to G in BMPR-IB has been reported in many breeds (Chu *et al.,* 2007).

IV – Conclusions

Amino acid substitutions were detected and repeated in higher and lower litter size animals, which can be used as marker-assisted selection for litter size trait in the goat breeds under study.

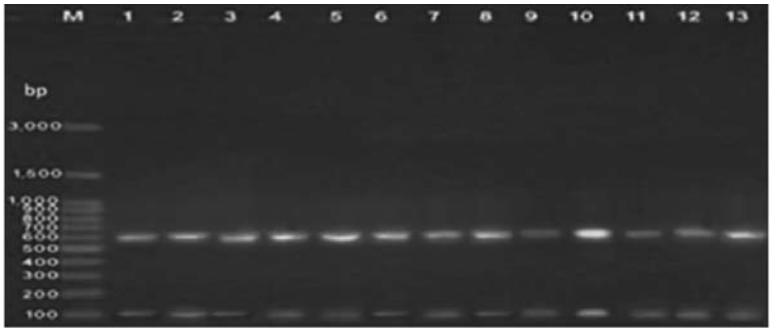

Fig. 3. Lanes (1-13) represents the PCR products of GDF9 gene of MB Zaraibi goat breed.

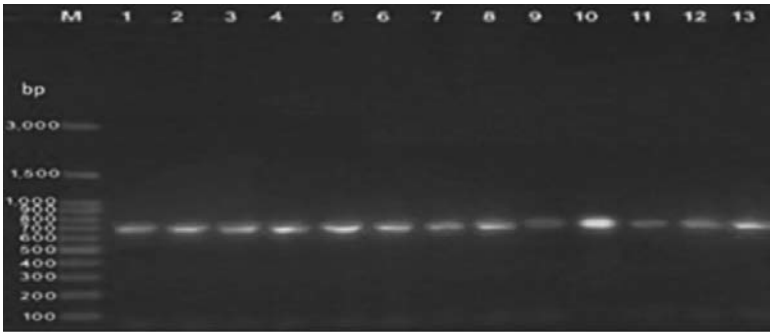

Fig. 4. Lanes (1-13) represents the PCR products of GDF9 gene of SB Zaraibi goat breed.

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Genomic bases of morphometric variations in small ruminants of Morocco

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Abstract. Small ruminants are one of the main sources of meat and milk around the world. The improvement and conservation of these species constitute major challenges for their sustainable contribution to the needs of human populations. Some morphological variations of individuals reflect the diversity of their adaptive potential and their zootechnical performances. The aim of this work is to analyze whole genome data of 160 unrelated local sheep, at a depth of 12X, sampled to represent the ecological and geographical diversity of Morocco. It aims at studying the genomic bases of their phenotypic variations by associating the genomic variations noted with the best possible resolution of the genomes (sequences of the complete genomes) with a certain number of morphometric indicators which affect the adaptive potential (ie. ears length) or the productive potential (ie. shoulder height, barrel tour). This association, carried out via genome wide association approaches (GWAS) will make it possible to highlight the possible genomic mutations responsible for these variations, among which we can identify those involved in adaptation to different climatic environments and those linked to the best zootechnical performances. These mutations should make it possible to incorporate these variations, after their validation, into selection schemes to improve the productivity of these species and their adaptability to certain climatic conditions.

Keywords. Sheep – Adaptation – SNP – GWAS.

Résumé. *Les petits ruminants sont l'une des principales sources de viande et de lait dans le monde. L'amélioration et la conservation de ces espèces constituent des défis majeurs pour leur soutien durable aux besoins des populations humaines dans ces produits. Certaines variations morphologiques d'individus reflètent la diversité de leur potentiel adaptatif et de leurs performances zootechniques. Le but de ce travail est d'analyser les données de génome entier de 160 moutons locaux non apparentés, à une profondeur de 12X, échantillonnés pour représenter la diversité écologique et géographique du Maroc. Il s'agit d'étudier les bases génomiques de leurs variations phénotypiques en associant les variations génomiques relevées à la meilleure résolution possible des génomes (séquences de génomes complets) avec un certain nombre d'indicateurs morphométriques qui affectent le potentiel adaptatif (longueur des oreilles) ou le potentiel de production (e.g. hauteur au garrot, tour des canons). Cette association, réalisée via des approches d'association pangénomique (GWAS), permettra de mettre en évidence les mutations génomiques possibles responsables de ces variations, parmi lesquelles nous pouvons identifier les acteurs de l'adaptation à différents environnements climatiques et ceux liés aux meilleures performances zootechniques. Ces mutations devraient permettre d'intégrer ces variations, après leur validation, dans des schémas de sélection visant à améliorer la productivité de ces espèces et leur adaptabilité à certaines conditions climatiques.*

Mots-clés. *Moutons – Adaptation – SNP – GWAS.*

I – Introduction

Small ruminants, especially sheep, are one of the main sources of meat and milk around the world. The improvement and conservation of these species are major challenges in meeting the needs of human populations in these commodities. Some morphological variations reflect the diversity

of their adaptive potential (e.g. length of ears ...) and productivity (e.g. shoulder height, cannon tour). These variations can serve as proxies to study local adaptation to constraining environments and to identify genes associated with the best zootechnical performance (e.g. meat production).

This research is part of this perspective to study the genomic bases of certain morphometric variations in sheep via Genome Wide Association approaches (GWAS) using their whole genomes. This is a work following the UE FP7 NextGen European project (Benjelloun, 2015) analysing 160 sheep representing the ecological, climatic and phenotypic diversity of Morocco. Here we present the results of a descriptive analysis of their genomes with one morphometric variable, as well as a description of the approach taken for the association studies (GWAS).

II – Material and methods

The sampled sheep are unrelated and represent the eco-climatic diversity of Morocco. They were selected so as to have the maximum distance between individuals over a very wide region of about 400,000 km^2. For each individual, tissue samples were taken from the distal part of the ear and then placed in alcohol for one day, after which they are transferred to a silica gel tube pending the extraction of DNA. A total of 412 herds were covered. The most important criterion was to optimize the selection of individuals to be sequenced to represent a wide range of environmental conditions and to ensure spatial representativeness of all regions, as described by Benjelloun (2015).

The complete genomes of the 160 selected sheep, representative of the entire Moroccan climate variation gradient, were sequenced (Whole Genome Sequencing) with a coverage rate of 12X. (Benjelloun, 2015).

Illumina readings for sheep were aligned to the sheep reference genome [OAR v3.1, GenBank assembly GCA_000317765.1 (Jiang *et al*., 2014)] and those for goats were aligned to the reference genome of the sheep.Variant discovery was performed using three different algorithms: Samtools Mpileup (Li *et al*., 2009), GATK UnifiedGenotyper (McKenna *et al*., 2010) and Freebayes (Garrison and Marth, 2012).

This study plans to use the Genome-wide efficient mixed-model analysis for association studies; the GEMMA program (Zhou and Stephens, 2012), which is one of the most accurate methods designed to identify genetic associations with observable traits, and which incorporates a model. Linear Mixed Model that takes into account population structure as well as other genetic background factors that may affect association testing.

The diagram illustrated in Fig. 1, summarizes the different steps that were performed for this test association between variants discovered and a phenotypic variable measured in the sampled sheep. In these steps, other softwares were used for processing the data (as explained in Fig. 1): VCFTOOLS (Danecek *et al.*, 2011), PLINK (Purcell *et al.,* 2007) and BIMBAM (Guan and Stephens, 2010).

III – Results and discussion

1. Polymorphism in sheep genomes

Around 39 million variants were successfully identified in sheep, 6.8% of which were small insertions/deletions (indels) and 2.1% showed more than two alleles. These results show a very high polymorphism in this species. Admixture analysis suggested a weak population structure, whose data were better explained by considering the existence of a single group of sheep (Benjelloun, 2015). However, a soft pattern of weak geographical structure appears when considering the existence of three homogeneous groups.

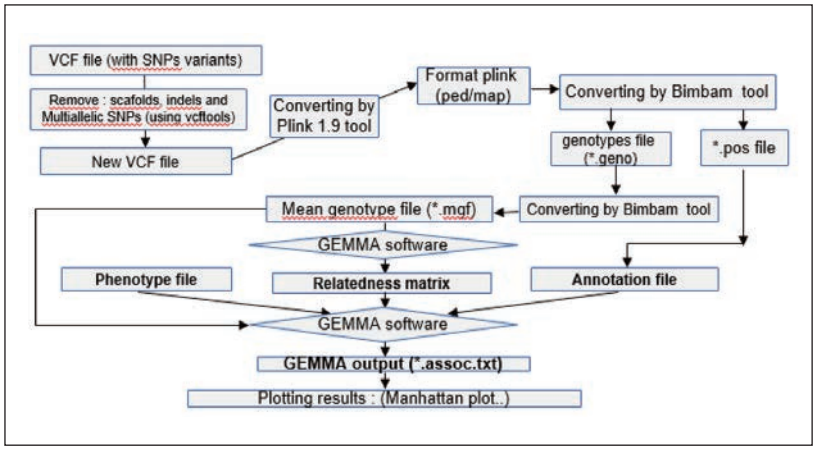

Fig. 1. Steps taken for association tests using GEMMA software.

2. GWAS results

The very strong polymorphism of the genomes of this species. The weak structuring of diversity shows that the sheep of Morocco represent a favourable biological model to the genotype/phenotype association tests at the genomic scale.

GWAS analyses identified several important significant signals at the genomic level in sheep that would be associated to the variation of certain morphometric characters measured in the sampled sheep. We present here the results relating to the character: 'Shoulder height' (Fig. 2), that shows a significant correlation between the studied phenotype and some SNPs on chromosomes 11, 16 and 20.

The method adopted thus makes it possible to identify certain SNPs in potential association with the expression of the studied phenotype. The analyses are being carried out to elucidate the potential role of these SNPs in the variation of the shoulder height in sheep as well as for other morphometric characters.

IV – Conclusion

The results of this study revealed several sites putatively related to the phenotype studied, despite the relatively limited number of individuals used in this study. This would be linked to the sampling strategy, which allowed a wide coverage of the phenotypic and environmental diversity present in Morocco, and the use of whole genome data. This work shows that the approach adopted ensures the feasibility of these genotype-phenotype association studies with the biological model used. Thus, the further identification of genomic regions involved in a wide range of morphometric variations of sheep.

This project will allow, later, to highlight the possible genomic mutations responsible for phenotypic variations among which we can identify those related to adaptation to different climatic environments. This should make it possible to integrate these variations, after their validation, into selection schemes in order to improve the adaptability of this species to different climatic conditions.

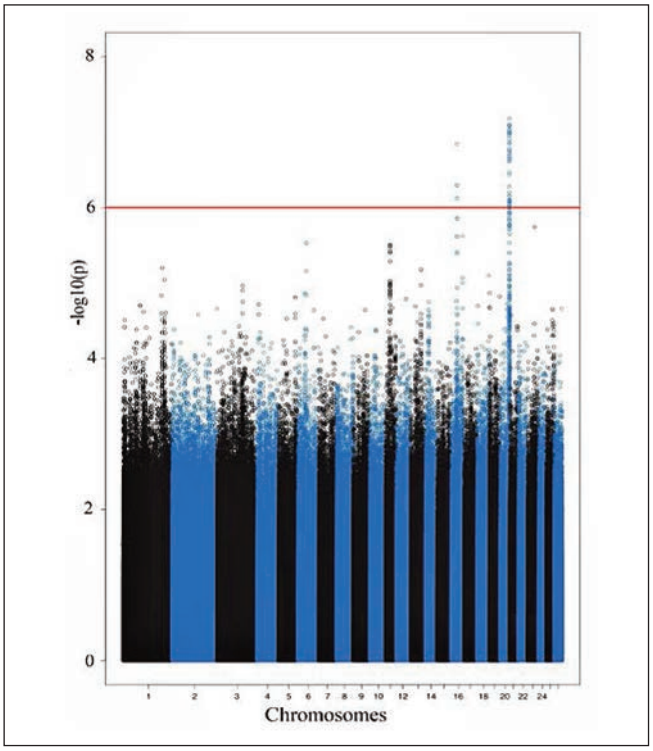

Fig. 2. Manhattan plot of the association of genotypes with the trait Shoulder height in sheep. Each point represents a SNP along 26 chromosomes of the genome. The horizontal line in blue represents the Bonferroni 5% threshold for which the association is considered significant.

Acknowledgments

These data were generated as part of the UE FP7 NextGen project. We would like to thank the consortium of this project for the data availability. We would also like to thank Florian J. Alberto for the precious help in carrying out this analysis.

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Management strategies that harness the adaptive capacities of small ruminants to improve herd resilience and efficiency.
Presentation of the ADAPT-HERD project

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Abstract. The main effect of climate change on livestock production systems in the Mediterranean area is to induce changes in feed resource availability. In face of constraining and changing environmental conditions, the challenge is to find practical solutions for herd management to minimize farmer's risk. These solutions should be good enough in terms of efficiency (E), to ensure sufficient income, and good enough in terms of resilience (R), to ensure farm sustainability. The objective of the ADAPT-HERD project is to develop simulation tools capable of evaluating the consequences of management strategies at the herd level, under contrasting and varying environments (Egypt, France, Spain and Tunisia). Our approach considers that biological adaptive capacities of small ruminants can be fully integrated within management strategies to improve R and E by: (i) using reproduction practices that provide the best match between herd demand and feed supply; (ii) managing groups of animals based on their adaptive capacities (targeting interventions) and (iii) managing herd demography to adapt animal numbers to future feed resources. The project will implement data acquisition at animal level (fine-grained experiments on adaptive capacities and phenotyping of local breeds) and at production system level (herd management, feed resource, climate and market conditions). Data will be combined and used in computer simulations to explore different climate change scenarios and management strategies and evaluate their effects on herd R and E. Interfacing modelling tools will be a key aspect of the project, fostering knowledge exchange and collaboration, especially with ongoing projects focusing on genetic selection and breeding solutions to improve R&E in small ruminants.

Keywords. Resilience – Efficiency – Climate change – Modelling.

Stratégies de gestion reposant sur la maitrise des capacités d'adaptation des petits ruminants pour améliorer l'efficacité et la résilience des troupeaux. Présentation du projet ADAPT-HERD

Résumé. *Un des principaux effets du changement climatique sur les systèmes d'élevage dans la zone Méditerranéenne est de modifier la disponibilité des ressources alimentaires. Face à ces conditions environnementales contraignantes et variables, l'enjeu est de trouver des solutions pratiques de gestion du troupeau pour minimiser les risques pour l'éleveur. Ces solutions doivent être satisfaisantes à la fois en termes d'efficacité (E), pour assurer un revenu suffisant, et en termes de résilience (R) pour assurer la durabilité de l'exploitation. L'objectif du projet ADAPT-HERD est de développer des outils de simulation permettant d'évaluer les conséquences de différentes stratégies de gestion du troupeau, dans des environnements contrastés et changeants (Egypte, France, Espagne et Tunisie). Notre approche considère que les capacités biologiques d'adaptation des petits ruminants peuvent être intégrées dans les stratégies de gestion du troupeau pour améliorer l'E et la R : i) en*

utilisant des pratiques de reproduction qui permettent une bonne adéquation entre la demande du troupeau et l'offre alimentaire ; ii) en gérant des groupes d'animaux basés sur leurs capacités d'adaptation (interventions ciblées) et iii) en gérant la démographie du troupeau pour adapter le nombre d'animaux aux futures ressources alimentaires. Le projet reposera sur l'acquisition de données au niveau de l'animal (expérimentations fines sur les capacités d'adaptation et phénotypage des races locales) et au niveau du système de production (pratiques de gestion, ressources alimentaires, conditions de marché). Les données seront combinées et intégrées dans des outils de simulation informatique pour explorer différents scénarios de changement climatique et de stratégies de gestion et ainsi évaluer leurs impacts sur l'E et la R du troupeau. L'interfaçage des outils de modélisation sera un aspect clé du projet, pour favoriser les échanges de connaissances et les collaborations, en particulier avec les projets en cours sur la sélection génétique pour améliorer l'E et la R des petits ruminants.

Mots-clés. *Résilience – Efficacité – Changement climatique – Modélisation.*

I – Introduction

The main effect of climate change on livestock production systems is to induce changes in resource availability. Rising temperatures and lower or unpredictable rainfall patterns decrease primary biomass production and thus forage availability. Changes in seasonality and the increasing occurrence of extreme events also greatly reduce the predictability of seasonal variations in food availability. These impacts of climate change will strongly affect performance of small ruminants' production systems, especially efficiency (E) as feed costs are one of the main element determining economic performance. Further the dynamic dimension of climate change impact implies that systems have to be able to recover from perturbations, that is to say have to be resilient (R). To face climate change impacts, the challenge is therefore to find solutions that improve both R and E of farms. The overriding concept behind the project ADAPT-HERD is that improving R&E at herd level will contribute to improve R&E at the farm level and therefore will be a key element of adaptation of small ruminant systems to climate change. The role of the herd as a key regulating element of farming system has already been demonstrated (Nozières *et al.*, 2011). Focusing on this particular element of the farming system makes sense in the Mediterranean context where the herd may be the only source of income and a major capital reserve for farmers (Aboul-Naga *et al.*, 2014). Given the complex balance of mechanisms giving rise to efficiency and resilience, there is no single solution that fits all and that will maximize both efficiency and resilience in a range of situations. The challenge is to find strategies that are good enough in terms of efficiency, to ensure sufficient income for farmers, and also good enough in terms of resilience, to ensure farm sustainability. In other words, the challenge is not to find an optimal strategy for R&E, but to explore how management strategies impact the relationship between R&E. Simulation tools, allowing "what if" scenarios to be evaluated would be extremely useful to assess the R&E costs and benefits of different management strategies under current condition, and also under future changing conditions.

Small ruminants are recognized for having strong biological mechanisms to deal with constraining and fluctuating environmental conditions, particularly with respect to feeding resources (Silanikove, 2000; Atti *et al.*, 2004). Our approach considers that such adaptive capacities can be fully integrated within management strategies to improve R&E at the herd level by:

– Using different reproduction practices to manage the temporal distribution of herd size and herd make-up (proportions of young and adult animals) that provides the best match between feed supply (itself varying in time depending on quantity and quality dynamics of the local resources such as grasslands, rangelands, crops, by-products) and overall herd demand (depending on the sum at any given time of individual requirements).

– Managing groups of animals in the herd based on their types of adaptive capacities and thereby targeting interventions to face resource shortage (e.g. extra feed distribution) to groups with the greatest potential to respond, reducing the total cost of intervention.
– Managing herd demography and adapting animal numbers to feed resource with locally-tailored replacement and culling practices that consider not only market conditions but also the continued viability of the herd.

II – Project overview

ADAPT-HERD is a 4-year project organized around 4 research work packages (WP), one outreach and dissemination WP and one management WP (Fig. 1). This structure facilitates the assembly of research results at two levels of organization, animal and herd, into operational tools to evaluate the impact of fluctuating resource due to climate change on R&E of small ruminants farming systems. The project contributes significantly to having a solid biological building-block at the animal level: WP1 provides knowledge on the mechanisms at the biological function level that give rise to adaptive capacities and WP2 provides knowledge on local breed phenotypes. The animal building block will be further used as the basis of individual variability when upscaling to herd level. WP3 provides information on herd management practices, feed resource diversity and dynamics, representative of the current context in the Mediterranean area. This information is integrated in WP4 to develop and implement herd models. Data collection and partners' expertise are used to build and simulate scenarios relevant in the PRIMA context. WP5 involves all partners and the broader networks of stakeholders in a participatory approach. It will manage the dissemination of models and simulation results by developing a user-friendly modelling toolbox. This interfacing component of the project will facilitate the use of deliverables as tools for educational objectives (understanding the complexity of herd functioning in changing environments) and strategic objectives (relevance of proposed solutions, improvement of models). It will also facilitate the diffusion of the protocol of data collection implemented in WP2 and WP3 to further extend the project approach to other potential Mediterranean partners.

III – Expected impacts

ADAPT-HERD will improve the ability of Mediterranean sheep and goat systems to adapt to climate change by providing herd management solutions based on animal adaptive capacities. The project will deliver locally tailored practical solutions for herd management to optimise production and resilience of the herd to minimize farmer risk in the face of constraining and changing environmental conditions. The project will also provide scientific knowledge on animal resilience. Experiments will quantify the impact of interactions between genotype and early-life environment on adult adaptive capacity. Phenotyping of local breeds will contribute to preserve longevity and optimize trade-offs in life functions (production vs survival). This will allows improving production while preserving local breeds' capacity to cope with constraints. "What if?" simulations of climate change and technical options scenarios will provide understanding costs and benefits of strategies in the current and future changing conditions, therefore supporting decision in rural development pathways. Finally, the project will deliver tools to enhance innovation capacity: protocol for data collection, common modelling architecture and user-friendly interface. Such tools will facilitate exchange and knowledge transfer between farmers, extension services, breeding organizations and policy makers.

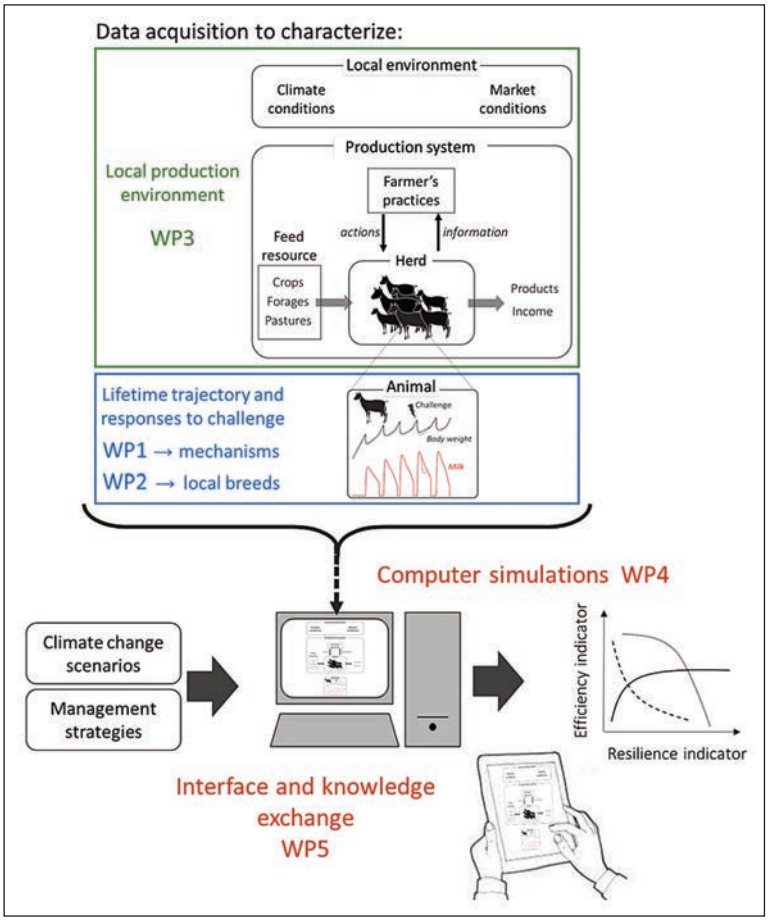

Fig. 1. Schematic of ADAPT-HERD workflow.

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Deroua a new synthetic breed for the improvement of sheep production in Morocco

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Abstract. Composite breeds are known for their capacity to combine traits of interest for increasing productivity in sheep production. They could also meet the needs of the breeders who want to simplify and facilitate herd management and animal self-renewal. The Deroua sheep is a new composite breed obtained by a continuous crossbreeding plan including two main indigenous Moroccan breeds: the Dman a prolific breed with 50% of genes and Boujaad a rustic breed with 50% of genes. The present study described the performance of 395 ewes and 976 lambs of the new breed collected between 2011 and early 2018. Fixed factors that influence significantly those performances were defined using linear models. Estimated parameters for Deroua new breed ewe and lamb were comparable to other good breeds, e.g. 1.61 lambs and 20.5 kg respectively for the prolificacy and the litter size at weaning per lambing. The results showed that all traits and especially growth performance were significantly influenced by the studied fixed factors (ewe age, sex and birth mode). Performance could be increased by selection with appropriate criteria. The new breed should be reared under actual breeding conditions to record performance in the field. However, it was already concluded that the new breed would constitute a valuable resource for improving sheep productivity in Morocco under suitable breeding conditions.

Keywords. Sheep breeding – Synthetic breeds – Deroua – Prolificacy – Morocco.

Deroua, une nouvelle race synthétique pour le développement de l'élevage ovin au Maroc

Résumé. *Les races synthétiques sont connues pour leurs aptitudes à combiner des traits complémentaires pour améliorer la productivité et l'efficience de l'élevage ovin. Elles permettent également de satisfaire les besoins des éleveurs désirant de simplifier la conduite de leurs troupeaux et d'assurer un auto-renouvellement facile des animaux. La race Deroua est une nouvelle race composite obtenue par un plan de croisement continu entre deux races locales marocaines : La Dman, une race connue pour sa prolificité et ses performances de reproduction élevées et la Boujaad, une race rustique ayant des performances de croissance améliorées, avec 50% des gènes chacune. La présente étude décrit les performances de reproduction de 395 brebis et de croissance pré-sevrage de 976 agneaux Deroua et les effets des facteurs environnementaux en utilisant des modèles linéaires pour les données collectées entre 2011 et 2018. Les paramètres estimés montrent des performances très satisfaisantes avec comme exemple une prolificité et un poids de portée au sevrage moyens de 1,61 agneaux et 20,5 kg de poids vif par agnelage respectivement. Les performances de croissance pré sevrage sont fortement influencées par les facteurs fixes étudiés (mode de naissance, âge de la mère et sexe). Ces performances pourront être davantage améliorées par la sélection d'animaux selon des schémas adaptés. La nouvelle race devrait ainsi constituer un vecteur important de développement de l'élevage ovin dans les zones agricoles favorables.*

Mots-clés. *Elevage ovin – Races synthétiques – Deroua – Prolificité – Maroc.*

I – Introduction

Composite breeds that combine traits of interest allow for optimizing sheep management, while meeting breeders' needs for increasing their production and renewing easily their flocks. Actually, increasing the number and weight of lambs produced per ewe remain the main challenge in meat sheep production. In this context, the development of the composite breed "Deroua" has been undertaken since 2002 at the National Institute of Agronomic Research INRA-Maroc at Deroua farm (32°17'35.9"N ;

6°33'38.6"W), located at 22 km east of Beni Mellal city. The purpose was to develop a new breed having a prolificacy close to 2 and improved reproduction and growth traits. The development was based on crossing Dman (50%-paternal) and Boujaad (50%-maternal) breeds. The former is characterized by improved reproduction traits such as high fertility and prolificacy (El Fadili, 2019) and the latter is known for its growth potential, meat quality and rusticity (El Fadili and Leroy 2001; El Fadili, 2004; Chikhi and Boujenane, 2003). Individuals of the composite breed were obtained for the first time in 2011 and performance records were made, together with several factors that might be associated with zootechnical performance of this breed. This paper aims at citing reproduction and growth performance of this new breed, based on its first non-selected nucleus of animals raised at the farm of origin, in relation with fixed factors such as the age of ewes and the year of production.

II – Materials and methods

1. Development of Deroua breed

To develop Deroua breed, the crossbreeding scheme was based on mating Dman rams with Boujaad ewes to produce the first generation F1, then to crossbreed F1 rams and ewes to produce the second generation F2, and to continue crossing until stabilizing zootechnical traits (Benjelloun *et al*., 2016). Preliminary analysis of different generations performance showed that the breed stabilized since the 5th generation (F5). Deroua sheep were produced for the first time at Deroua farm of INRA in 2011, 9 years after the start of the program. Sheep were raised indoors under similar reproductive, feeding and prophylactic conditions and on an annual breeding cycle. Rams and ewes with major defects (e.g. rams with one testicle, adult weight <30kg for rams and <25kg for ewes, repetitive health issues) were discarded for reproduction.

2. Reproduction, feeding and prophylactic conditions

Groups of 10-20 ewes were formed and maintained during the program. Males produced within the different groups were used as rams to mate non closely related animals (half-sister/brother). No selection based on zootechnical performance was applied at this stage. Ewes were weighted and exposed to males during 60 days (mostly during June and July) and penned in the ratio 10 to 20 ewes per ram. Ewes were flushed starting 10 days before breeding. Sheep feeding was based mainly on fresh alfalfa, alfalfa hay, cereal straw or corn silage depending on the period and availability. Furthermore, sheep were supplemented with concentrates using barley, sunflower cake or dry beet pulp, depending on physiological state of the animals (reproduction, end of lactation, beginning of gestation…). Prophylactic and sanitary treatments consisted in preventing against enterotoxemia, sheep pox, myopathy and internal and external parasites.

3. Performance checks and studied traits

During the lambing period, born lambs were identified and weighed in the first twelve hours of their life. Then, lambs were weighted every two weeks until weaning. Those weights were used to infer weights at 30 and 90 days and growth rate before weaning. The traits used to assess zootechnical performance of the new breed were (i) fertility, litter size and weight at birth and weaning, as well as pregnancy duration in ewes; (ii) Weight at birth (W0), at 30 (W30) and at 90 days (W90) as well as survival rate at 90 days (SUR90) together with growth rate between birth and 30 days (ADG030) and between 30 and 90 days (ADG3090). Those traits were inferred for 395 ewes and 976 lambs between 2011 and early 2018.

4. Data analysis

Descriptive data (means and standard deviations) were computed using R software (R version 3.5.3; 2019). In order to highlight the effects of fixed factors, variance analysis was performed using linear model via the "LM" function of the same software. The model used for ewe traits was:

$$(Variable\text{-}to\text{-}explain)_{jkl} = \mu + (Year\text{-}of\text{-}lambing)_j + (Age\text{-}class\text{-}lambing)_k + b * (Breeding\text{-}weight)_l + e_{jkl}$$

The model used for lamb traits was:

$$(Variable\text{-}to\text{-}explain)_{ijkl} = \mu + (Birth\text{-}mode)_i + (Sex)_j + (Mother\text{-}Age\text{-}class)_k + (Year\text{-}of\text{-}birth)_l + e_{ijkl}$$

Adjusted means and standard deviations were estimated using the function "lsmeans" of the R package "LSMEANS". The quantified effect associated with each level of the studied factors on the zootechnical performances was estimated via the "contrast" function and the "eff" method of the same R package.

III – Results and discussion

1. Ewe performance

The 395 Deroua ewes recorded an average (± sd) fertility of 81 (±39)%. They realized a prolificacy of 1.61 (±0.78) lambs/lambing and a litter weight of 5.12 (±1.88) kg/lambing. The size and weight of litter at weaning was 1.21 (±0.66) lambs and 20.5 (±8.1) kg/ewe. Gestation duration was 151 (±1) days (Table 1).

Lambing performance obtained here is comparable to that of DS breed resulting from the crossbreeding "Dman x Sardi" which registered 82% for fertility, 1.57 lambs/lambing for prolificacy and 20.1 kg for the litter weight at weaning (Boujenane, 2002). However, it is worth mentioning that this last study reported adjusted averages for the fixed factors studied. Moreover, the fertility and prolificacy we obtained are comparable to the performance of the synthetic breed INRA180 resulting from the crossbreeding "Dman x Timahdite", which registred 91% for fertility and 1.6 lambs for prolificacy. However, the latter breed achieves a greater litter weight at weaning reaching 25.5 kg (El Fadili, 2011).

Fixed factors of the linear models that were used explained between 5% (for the prolificacy) and 22% (for the litter weight at weaning) of the overall variation of the studied traits. All of the studied traits were significantly impacted by the year of lambing (3-10% of the overall variation of the studied traits). Low performance was obtained in years 2015 and 2016 compared to the rest years of recording, except for fertility. The age class affects significantly the weight of the litter at lambing and weaning and the litter size at weaning with higher performances obtained by multiparous ewes in comparison with the primiparous ones (Fig. 1A). Furthermore, the weight of the ewe increases significantly the weight of the litter at weaning. The average ratio is 0.25 kg of litter weight each 1 kg of ewe weight.

2. Lamb performances

The lamb growth traits (±sd) were on average 3.19 (±0.77) for the weight at birth (W0) and 16.8 (± 4.3) kg for the weight at weaning. Growth rate averaged at 159 (± 61) g before 30 days and 146 (± 50) g between 30 and 90 days. Survival of lambs at weaning was rather low: 75% as an average (Table 1).

Lamb growth performance obtained here was higher than those of DS lambs, which weighted 2.69, 6.65 and 15.8 kg at birth, 30 and 90 days (Boujenane, 2002). Similarly, Deroua lambs performed similar to lambs of the INRA180 synthetic breed, which achieved 3.01 and 7.23 kg respectively at birth and at 30 days. However INRA180 lambs weighed 17.4 kg at 90 days (El Fadili, 2011). How-

ever, the survival at weaning recorded by Deroua lambs is substantially lower than that achieved by both DS and INRA180 synthetic breeds, which are respectively 87 and 84% viable (El Fadili 2011). The limited survival rate can be partially explained by the permanent stabling mode, which is marked by some climatic/husbandry concerns that could occur during some periods.

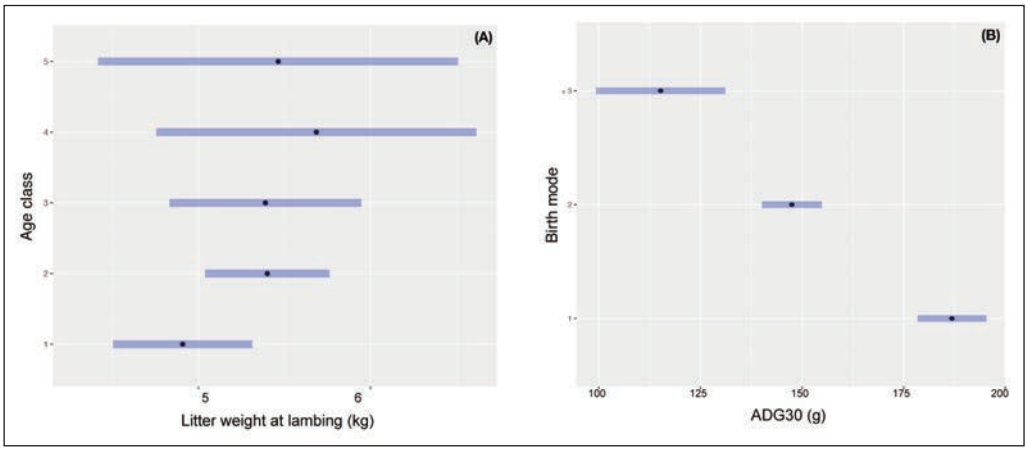

Fig. 1. Adjusted means of (A) litter weight at lambing of ewes depending their age at breeding and of (B) average growth rate of lambs according to their birth mode. Age classes are defined by the ewe age at lambing (1: ≤ 30, 2: 30-42, 3: 42-54, 4: 54-66, 5: 66-78 months old). Birth modes are denoted by 1: single-born, 2: double-born, ≥3: triplets and greater.

Table 1. Average performance on different lamb traits, standard deviations and fixed factors impacting these

Trait	BW (kg)	W30 (kg)	W90 (kg)	ADG030 (g)	ADG3090 (g)	SUR90
Mean ± SD	3.19 ± 0.77	7.99 ± 2.23	16.8 ± 4.3	159 ± 61	146 ± 50	0.75 ± 0.44
Proportion of variance explained by the studied fixed factors (%)	36	32	27	26	25	6
Significative fixed factors	Birth mode (***) Sex (***) Year (**)	Birth mode (***) Mother age (***) Year (***)	Birth mode (***) Sex (***) Year (***)	Birth mode (***) Mother age (***) Year (***)	Birth mode (***) Sex (***) Year (***)	Birth mode (***) Mother age (***) Year (*)

* p<0.05; ** p<0.01; *** p<0.001.

The fixed factors included in the models explained 25 to 36% of the overall variations of the pre-weaning weights and growing speeds. However, the model used to study survival at weaning explained only 6% of its overall variation (Table 1). The birth mode was by far the main factor that affects significantly all the studied traits (17-32% of the variation of the weights, 7-13% of the variation of the ADG and 3% of the variation of survival at weaning) where single-born lambs were heavier (+0.82 and +1.35 kg for W0, +1.9 and +3.4 for W30 and +3.3 and +5.8 for W90 when compared respectively to double-born and triplets and greater lambs). Similarly, they grew much faster than multiple-born lambs (e.g. Fig. 1B). The effect of this factor on growth characteristics is consistent with the results of most authors on the main Moroccan breeds (El Fadili 2011; El Fadili 2008; Benjelloun 2002, Chikhi 2002; El Fadili & Leroy, 1997). Lamb sex affected significantly the weights at birth and at weaning as well as ADG3090 for which males were heavier and grew faster than females. Average weight difference at weaning was 0.76 kg. The impact of the birth year was significant on all of the studied traits. It was less prominent but significant on W0 and survival at wean-

ing. Lambs born in late 2013, 2016 and 2017 were heavier and grew faster in comparison with those born in late 2011, 2014 and 2015. However survival was high in 2014 and 2015 as well. Considering that the studied sheep were kept continuously indoors, the year could affect sheep performance due to the quality of alfalfa or corn silage made available in each year. Ewe age at birth affected all traits except for ADG3090. Products of multiparous registered higher performances than primiparous lambs. This is consistent with previous studies on Moroccan sheep breeds (El Fadili 2011; El Fadili 2008; El Fadili 2007a; Al Fadili 2007b; Benjelloun 2002; Chikhi 2002; El Fadili and Leroy, 1997).

Rearing Deroua sheep under different conditions would help in getting more information on how the new breed would behave under actual breeding conditions. This would help in depicting additional fixed factors that could impact its performances.

IV – Conclusion

This study highlighted for the first time ewe and lamb zootechnical performance of Deroua the new synthetic sheep breed. It is based on data collected from the first non-selected core of animals of the new breed raised in one farm where conditions are not always perfect. Despite this, performances obtained here are encouraging and comparable with the main previously developed synthetic breeds in Morocco. They allow concluding that the new breed can represent a new genetic resource that could increase sheep productivity. Besides, Morphometric measurements would help in characterizing morphology and standards of the new breed.

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Economic analysis of Moroccan sheep breeds' conservation

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Abstract. As in many countries, animal production in Morocco has an important economic, social and nutritional role. However, the conservation of animal genetic resources is still carried out by in situ methods. In order to optimize the sustainable management of animal genetic resources, the economic assessment of animal genetic biodiversity is important. In this case study, we compared the economic value of the main animal breeds In Morocco. Animal breeds selected are prominent in the country, in particular, Beni Guil, Ouled Jellal, Sardi, Timahdit and Dman. Data collection of production costs and sale prices was carried out among farmers and organizations working in the sheep farming sector in Morocco. An economic weighting analysis was implemented in which the marginal profit of breeds was assessed. The economic importance of a character can be expressed by the marginal profit, which results from the increase of a unit of this character above the average of the studied breeds. In this approach, two economic values were computed. The financial market value of each breed is added to another value related to the private genomic polymorphism. The results showed that the price of the Dman breed would undergo the important increase that is around 3.3 MAD/kg considering that this breed has the largest number of exclusive variants and an important effective population size. Overall, this work may be of interest to policy makers in guiding development programs and projects to encourage breeds that have important adaptation values.

Keywords. Economic analysis – Sheep breeds – Private genomic polymorphism – Economic value – Morocco.

Analyse économique de la conservation des races ovines marocaines

Résumé. *Comme dans de nombreux pays, la production animale au Maroc joue un rôle économique, social et nutritionnel très important. Néanmoins, la conservation des ressources génétiques animales se fait toujours à travers des méthodes in situ. Afin d'optimiser la gestion durable des ressources génétiques animales, l'évaluation économique de la biodiversité génétique animale est vivement conseillée. Dans ce cas d'étude, nous avons comparé la valeur économique des principales races animales. Les races animales sélectionnées sont les races les plus dominantes du pays, en particulier les races Beni Guil, Ouled Jellal, Sardi, Timahdit et Dman. La collecte de données sur les coûts de production et les prix de vente a été réalisée auprès des agriculteurs et des organisations travaillant dans le secteur de l'élevage ovin au Maroc. Une analyse de pondération économique a été réalisée dans laquelle le bénéfice marginal des races a été évalué. L'importance économique d'un caractère peut s'exprimer par le profit marginal résultant de l'augmentation d'une unité de ce caractère au-dessus de la moyenne des races étudiées. Dans cette approche, deux valeurs économiques ont été calculées. La valeur marchande financière de chaque race, en plus d'une autre valeur liée au polymorphisme génomique privé de certaines races. Les résultats montrent que la race Dman a été concernée par la plus grande valeur économique d'adaptation 3,3 MAD/kg, sachant que cette race possède le plus grand nombre de variantes exclusives et une taille effective importante. Dans l'ensemble, ce travail pourrait intéresser les décideurs politiques pour orienter les programmes et projets de développement en vue d'encourager les races qui ont une valeur économique importante en matière d'adaptation.*

Mots-clés. *Analyse économique – Races ovines – Polymorphisme génomique privé – Valeur économique – Maroc.*

I – Introduction

Climate change is considered as the greatest future threat of animal production (WGI AR5, IPCC 2013). Livestock biodiversity is the most important safeguard against this threat, ensuring sustainability and resilience of production systems. The most important threats to biodiversity are related to the marginalization of traditional production systems and associated local breeds, mainly due to the expansion of intensive livestock production, often on a large scale and using a limited number of breeds (FAO, 2015). At the global level, erosion of animal genetic resources is rapidly occurring and genetic diversity is decreasing (Pizzi *et al*., 2016). As a result, many countries are losing their genetic resources, essential for both food security and sustainable development. Thus, the economic assessment of genetic diversity indicators including inferences of the adaptive potential of local breeds seem to be crucial in this context of climate change and global erosion of biodiversity and pastoral/forage resources. Thus, the main objective of this research is to assess the economic value of five sheep breeds raised in Morocco while including market and other non-market values related to their genetic diversity.

II – Materials and methods

1. Economic analysis

In order to preserve genetic diversity of livestock, IMAGE project "Innovative Management of Animal Genetic Resources" adopts a socio-economic approach to compare the economic importance of indigenous animal breeds. The breeds included are among the most important in Morocco, namely: Dman, Sardi, Beni Guill, Oulad Jellal and Timahdite.

For genetic resources, which have no market value, their economic assessment is done indirectly. In general, the value used is the wealth created by economic activities dependent on the existence of genetic resources (Lévêque and Glachant, 1992). The economic valuation allows assessing the biological diversity components for the purpose of its conservation and sustainable use.

An analysis of the economic weights was performed in which the marginal profit of the breeds was evaluated. The economic importance of a character is expressed by the marginal profit resulting from the increase of one unit of the character above the average of the studied breeds (Schlote, 1977). The marginal profit was calculated using the difference between marginal revenue and marginal cost.

2. Data collection

In this research, two indicators of genetic diversity were used to evaluate each breed, namely the number of exclusive variants at the genome level and the effective population size. Exclusive variants were estimated from global genomic variants using the perl vcf-compare module of vcftools (Danececk *et al*., 2011). Current effective population sizes (*Ne*) were inferred through the PopsizeABC algorithm (Boitard *et al*., 2016). They were estimated at the level of each breed studied using the complete genome data of individuals (Benjelloun, 2015).

For data on sales prices and production costs used, data collection was carried out in 2018 among farmers and organizations working in the sheep farming sector in Beni Mellal-Khénifra, Sous Massa, Errachidia and the Eastern region of Morocco.

III – Results and discussion

The economic analysis aims to compare the economic value of major animal breeds. Two economic values were calculated. The financial market value of each breed in addition to another value related to private genomic polymorphism that contributes to the individual variations of each breed. The latter is illustrated by the number of private mutations in their genomes and used as a proxy for "adaptation value" in the context of environmental changes.

The advantage of this approach lies in the fact of combining both market values, such as cost or price, and non-market values such as genomic variation. Results showed that high levels of genomic diversity characterize all the studied breeds. Similarly, their effective population sizes are very high in comparison with "industrial" breeds (Table 1).

Table 1. Exclusive variants and Effective size of studied breeds

Breed	Exclusive variants	Effective population size (*Ne*)
Dman	1,783,651	30,052
Sardi	1,621,728	28,296
OuledDjellal	460,461	26,367
BeniGuil	341,296	32,223
Timahdite	934,212	43,781

The profit calculation is based on an inventory of production costs and selling prices by breed. Costs include feeding costs, guarding, veterinary fees, and the value of lamb after weaning for each breed. Table 2 presents the average total cost estimates and the average selling price per breed reported per kilogram live weight.

Table 2. Total cost and selling price by breed

Breed	Production cost (MAD/kg)	Selling price (MAD/kg)
Dman	31.8	38
Sardi	45.1	51
OuledDjellal	35.9	43
BeniGuil	34.7	41
Timahdite	34.1	40
Average	36.3	42.6

Once the marginal profit was estimated, we inferred the economic value of genetic characters by multiplying the marginal profit and the weight of each character. The results show that the price of Dman breed will be affected by the greatest increase, despite the fact that this breed remains the least profitable on the market. This recorded increase was 3.3 MAD/kg considering that this breed has the most important number of exclusive variants and a very important effective population size. Then, Sardi breed with a recommended increase of its selling price of 2.7 MAD/kg. It is marked by a high genetic diversity uniqueness as Dman breed (Table 1) and also a very high economic profitability. Timahdit was third in term of its economic value with an increase value of its selling price of 2.5 MAD/kg, followed by Oulad Jellal and Beni Guill breeds with recommended increases of 2 and 1.7 MAD/kg respectively (Table 3).

Table 3. Calculation results of the economic value

Breed	Variation in marginal profit	Economic weighting according to genetic character (MAD/kg)		Economic value of genetic character (MAD)	Economic value (MAD/kg)
		No. of exclusive variants	Current effective size		
Dman	0.99	2.14	1.16	3.3	41.3
Sardi	0.93	1.72	0.96	2.7	53.7
OuledDjellal	1.13	0.72	1.31	2.0	45.0
BeniGuil	1.00	0.42	1.27	1.7	42.7
Timahdite	0.94	1.01	1.52	2.5	42.5

IV – Conclusions

This research focused on comparing the economic value of five major sheep breeds in Morocco, namely Beni Guil, Ouled Jellal, Dman, Sardi and Timahdit. To calculate this value, we combined both market values, such as raising costs and selling prices, and non-market values such as the adaptive potential represented by two indicators, namely, the number of exclusive variants and the effective population size. The results showed differences in the economic value of adaptation between these breeds. The Dman breed, which is not enough supported by animal development projects, has been affected by the greater economic value of genetic diversity, followed successively by Sardi, Tmahdit, Oulad Jellal and BeniGuill. These results would provide guidelines for development programs and projects in the country to encourage breeds that have high unique diversity.

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Round table on pastoralists and extensive livestock farmers

Roles of pastoral networks for sustainable rangeland management

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Summary. Pastoral resources are deteriorating more and more. One of the causes of degradation is the users' perception of collective resources, exploiting them with a disregard for others. The rights of pastoral communities are deteriorating further due to the development policies implemented. Pastoral communities have knowledge of rangeland management and need land security as well as policies that take them into consideration. Pastoral policies should involve pastoral communities in decision-making processes related to the sustainable use, development and conservation of pastoral resources, and in pastoral resource planning and management programmes. Networking is one of the essential tools in sustainable management and in sharing knowledge acquired through learning and experience in the development of natural resources. At an international level networking is a powerful channel to disseminate and generalize information to increase awareness of the value that a common resource has for the sustainable management of natural resources by combining ancestral knowledge and modern forms of organization. Networks also make it possible to advocate for pastoral communities and the sustainable management of natural resources. The Arab Network of Pastoral Communities, which was initiated by IUCN West Asia in Amman 2016, brings together civil society organizations, researchers, experts, policymakers and other stakeholders.

Keywords. Pastoralism – Networks – Pastoral Communities.

Rôles des réseaux de pasteurs pour une gestion durable des parcours

Résumé. *Les ressources pastorales se dégradent de plus en plus ; parmi les causes de dégradation, la perception des usagers des ressources collectives, chacun veut en tirer le maximum sans se soucier des autres. Les droits des communautés pastorales se dégradent de plus en plus à cause des politiques de développement mises en œuvre. Les communautés pastorales ont des savoirs concernant la gestion des parcours, ont besoin d'une sécurisation des terres et de politiques qui les prennent en compte. Les politiques pastorales doivent faire participer les communautés pastorales à la prise de décisions sur les questions concernant l'utilisation durable, la mise en valeur et la conservation de ces ressources pastorales et aux programmes de planification et de gestion des ressources pastorales. Le réseautage est un des outils essentiels à la fois dans la gestion durable, et dans le partage des connaissances de l'apprentissage et l'expérience dans le développement des ressources naturelles. Au niveau international, le réseautage constitue une voie considérable dans la diffusion, la généralisation de l'information pour le développement de la perception de l'intérêt de la chose collective ce qui permet la gestion durable des ressources naturelles en combinant le savoir ancestral et les modes d'organisation modernes. Les réseaux permettent aussi de plaider en faveur des communautés pastorales et de la gestion durable des ressources naturelles. Le Réseau Arabe des Communautés Pastorales qui a été initié par l'UICN Asie de l'Ouest à Amman 2016, regroupe les organisations de la société civile, des chercheurs, des experts, des décideurs et d'autres parties prenantes.*

Mots-clés. *Pastoralisme – Réseaux – Communautés Pastorales.*

I – Introduction

Networking is one of the essential tools in both sustainable management and sharing knowledge acquired through learning and experience in natural resource development.

A professional network is about getting information, increasing visibility and making connections and building relationships with others. The network allows us to benefit from the experience of others.

At the international level, networking constitutes a powerful channel in the dissemination and generalization of information.

II – Role of communication with the pastoral communities for policy development

Local pastoral communities, whether they are grouped within professional organizations or not, know how to manage land well and contribute enormously, but they need land security and policies that take them into account. It is necessary to ensure the participation of pastoral communities and all decision-makers at national level on issues related to the sustainable use, development and conservation of these pastoral resources.

There is a need for management approaches that combine the best of traditional knowledge of pastoralist communities with modern technologies and for integrated management practices to be applied.

Making pastoral communities accountable for the resources they use is the foundation for sound management and use of land-related resources (WISP, 2008).

III – Benefits of consulting all stakeholders in the planning, development and management of pastoral resources

Local communities and pastoralist associations own and manage pastoral resources and their livestock. As such they have made a significant contribution in the past. It is these same modalities that must be preserved so that society can derive better benefits.

Pastoral communities can derive three benefits from active participation in pastoral and animal genetic resource planning and management programmes:

- They receive a fair share of the benefits arising from the use of pastoral resources.
- They benefit from training programmes, technology transfer, generation and dissemination of information on pastoral resources.
- They accept the establishment of pastoral laws and codes of conduct and good management practice of pastoral resources (Davies *et al.,* 2016).

IV – Case of the rangelands in eastern Morocco

Eastern Morocco covers an area of 32 million hectares of which 3.7 million hectares are rangelands, with about 9 000 herders who maintain a population of 1 million sheep, goats and camels. Livestock production is pastoral and mobility depends on good and bad years and on the economic situation of families. The rangelands contribute greatly to the feeding of the herds and they are collective for several tribes (Mahdi, 2009). A farmer can freely use a pasture, whatever his cooperative and community.

1. Main problems of the rangelands and adopted solutions

Key issues that involve the sustainable and conservative management of pastoral resources are:

- Inter and intra-tribal conflicts over pastoral resources.
- Clearing and cultivation of rangelands.
- Enclosure and appropriation of pastoral areas (Zniga) (Bourbouze *et al*., 2009).

The solutions adopted include the transfer of rangeland management to pastoral cooperatives and the establishment of partnership contracts with these pastoral cooperatives. These contract agreements with the population have several objectives (Davies *et al*., 2016):

- Empowerment of pastoral communities in the sustainable management of pastoral heritage in a partnership framework.
- Development and management of the rangelands.
- Involvement and engagement of the population in local sustainable development.
- To establish the conditions of transfer of competence to professional organizations.
- To determine the financing conditions.
- To introduce management bonuses to avoid overstocking rangelands.

2. The organization of pastoral communities in pastoral cooperatives

The organization of pastoral communities in cooperatives is based on the pastoral populations who collectively hold the rights of use of the rangeland. The tribe or the pastoral communities are replaced by the pastoral cooperative called ethno-lineage with clear statutes. In order to belong to a cooperative it is necessary to be a member of the local ethnic group. The cooperative is a "grafting" of an institution governed by modern laws onto traditional and tribal social structures governed by customary law.

Representativeness in the cooperative office follows the principle of respect for the tribal balance, namely one representative per lineage.

The organization of pastoralists in the pastoral cooperative transforms their status of trustee on the customary pastoral lands of the tribe governed by custom to the status of full right members of a cooperative. But the two logics confront one other and give rise to conflicts of interest.

34 pastoral cooperatives were created by the PDPEO: There are 17 in the northern zone and each pastoral cooperative corresponds to an ethnic community in the southern zone. (Mahdi, 2009).

3. Networking cooperatives in cooperative unions

The creation of a "Mahmia" or "Hima" protection zone and the definition of access rules are handled by a new institution: the Union of Cooperatives, the Union is the modern form of the fusion of lineages. through their cooperative, around the management of the rangelands. Representation within the Union follows the principle of respect for the tribal balance, i.e. one representative per cooperative.

The Union of Cooperatives is established as a space for representation and consultation of the pastoral communities. It is also illustrated by the active role it plays in the supply of livestock feeds, rest management, collection of grazing fees and fines, etc.

The Union has proved to be an effective organ for the mobilization and supervision of pastoralists and an active stakeholder in civil society. The activities of the Union of Cooperatives went beyond the pastoral framework to extend to the social framework, such as the vaccination of children (Mahdi, 2009).

V – The Arab Network of Pastoral Communities

The Arab Network of Pastoral Communities brings together civil society organizations, researchers, experts, policymakers and other stakeholders, it was initiated by IUCN West Asia whose leaders were aware of the importance of networking as essential tools in the sustainable management of natural resources in the region and the sharing of knowledge, learning and experience in development.

The network of pastoral communities was created by the representatives of 8 countries, Algeria, Egypt, Jordan, Lebanon, Morocco, Palestine, Sudan, Tunisia. 3 other countries joined the network, Mauritania, Bahrain and Libya

The Arab Network of Pastoral Communities was established in Amman, Jordan in September 2016 (Agaroual and Asfour, 2016).

The Arab Network of Pastoral Communities was launched on the occasion of the second Regional Forum on HIMA which took place in Amman on October 17th and 18th, 2016.

1. The main objective of the Arab Network of Pastoral Communities

The main objective of the Arab Network of Pastoral Communities is to revive, document and develop traditional knowledge in the Arab region to effectively involve the pastoral communities in the rehabilitation and improvement of sustainable pasture management.

2. Objectives of the Arab Network of Pastoral Communities

The Arab Network of Pastoral Communities aims to:

- Promote capacity building, shared learning, networking and exchange of experiences of indigenous peoples (local communities) in the region, sharing a deep concern for the respect of cultural rights and land rights and natural resources.
- Promote and develop traditional knowledge in the Arab region with a view to investing in the development of pastoral communities' FOs and strengthen their capacities for effective participation in the rehabilitation and improvement of participatory sustainable rangeland management.
- Encourage the application of systemic approaches to rangeland management.
- Increase knowledge, ideas and awareness of systemic approaches to sustainable natural resource management in the region. This will be made possible through the collection of available knowledge on systemic approaches to integrated natural resource management and sharing it with targeted experts; which will reflect positively on the governance of natural resources.
- Develop and disseminate documents on traditional knowledge of the Arab region.

3. General structure of the Arab Network of Pastoral Communities

The Network of Pastoral Communities has been structured according to the proposal of IUCN West Asia officials (see Fig.1 below). (IUCN West Asia Amman, Jordan)

The main body is made up of representatives of pastoral communities belonging to the Network from countries' national networks (the inner circle).

A body of regional institutions (Membership Support Network) that, through their mandate and interest, could support the network and activities of the Network of Pastoral Communities (the outer circle).

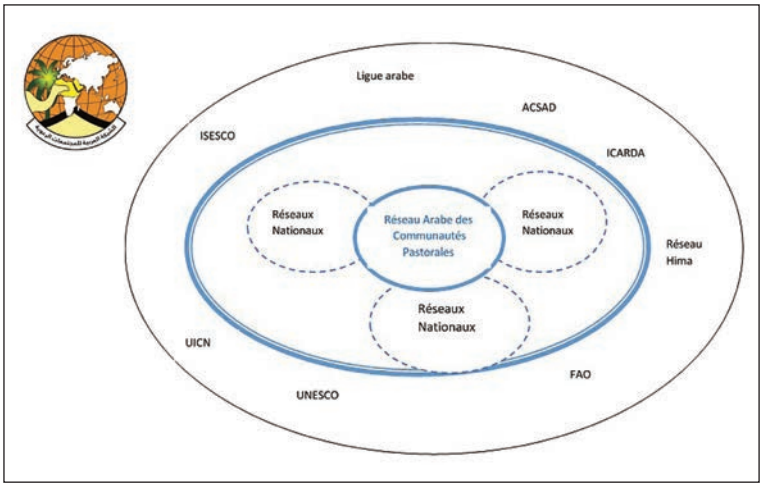

Fig. 1. General structure of the Arab Network of Pastoral Communities.

4. Functions of the Arab Network of Pastoral Communities

The main functions of the Network are:

- To ensure the representation and defence of pastoral communities in local and international forums.
- To strengthen the role of pastoral style in economic and social development, food security and nature conservation.
- To strengthen the role of youth and women in the sustainable development of pastoral style use as a productive approach.
- To document local knowledge that takes into account and disseminates gender.
- To strengthen the participatory approach taking into account the integration of pastoral communities in the management of natural resources.
- To ensure the integration of traditional knowledge and culture that is associated with pastoral communities in national education and awareness programmes.
- To integrate regional and global networks.
- To share and disseminate what is learned and experiences.
- To provide a platform for exchange, consultation and cooperation among network members and the exchange of experiences between Arab countries.
- To encourage the implementation of pilot projects to disseminate local knowledge in natural resource management such as the Hima / Agdal approach, which reinforces the role of pastoral communities.

VI – Conclusion

Pastoral resources are deteriorating more and more. One of the causes of degradation is the users' perception of collective resources, exploiting them with disregard for others.

Also, the law of pastoral communities is deteriorating further because of the development policies implemented.

Networking is a powerful channel to disseminate and generalize information to increase awareness of the value that a common resource has for the sustainable management of natural resources by combining ancestral knowledge and modern forms of organization.

The Networks also make it possible to advocate for pastoral communities and the sustainable management of natural resources.

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Abbreviations

CIHEAM: International Centre for Advanced Mediterranean Agronomic Studies.
FAO: Food & Agriculture Organization.
IUCN ROWA: The International Union for Nature Conservation Regional Office for West Asia Amman.
WISP: The World Initiative for Sustainable Pastoralism.

Sheep shepherds in the Algerian agro-pastoral steppes: Which reading?

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Abstract. The shepherd remains one of the essential professions in the small ruminant breeding sector. His work plays a major role in feeding grazing animals and is an additional guarantee for food security. However, the transformation of the Algerian steppes under the joint influence of economic, territorial, agricultural and environmental policies has made it difficult to recruit shepherd by the herders. This communication presents the difficulties and challenges faced by herders in hiring a competent shepherd. Hence our questioning on the situation of shepherds and the consequences of changes in livestock farming on the future of this profession. To this end, group interviews and surveys of 100 herders were carried out in the municipality of El-Guedid-Algeria. Our analyses made it possible to obtain information characterizing the shepherd's profession. Our results confirm the decisive role of the shepherd in herd management. Indeed, 73% of the herders surveyed used the shepherd service. Their salaries are based on the size of the herd and the farming system. They vary from 15,000 to 70,000 dinars/month (100 to 466€). Mobile shepherds receive a higher salary than sedentary shepherds. However, they considered that these salaries did not reflect the work done throughout the year (herding, night-time animal surveillance, animal care, feed distribution, etc.). It is noted that an essential prospective aspect to revalue this profession: 65% of the children of shepherds surveyed are not in favor of doing this job.

Keywords. Shepherd – Issues – Profession – Livestock systems – Salaries, agropastoralism.

Les bergers ovins en steppes algériennes agropastorales : Quelle lecture ?

***Résumé**. Le berger reste un des métiers incontournables du secteur de l'élevage de petits ruminants. Son travail joue un rôle majeur pour l'alimentation des animaux au pâturage et constitue ainsi une garantie supplémentaire pour la sécurité alimentaire. Cependant, la transformation des steppes algériennes sous l'influence conjointe des politiques économiques, territoriales, agricoles et environnementales a rendu difficile le recrutement des bergers. Cette communication présente les difficultés et les enjeux auxquels sont confrontés les éleveurs pour acquérir un berger compétent. D'où notre questionnement sur la situation des bergers et les conséquences des mutations de l'élevage sur l'avenir de ce métier. Pour se faire, des entretiens de groupes et des enquêtes auprès de 100 éleveurs ont été réalisées dans la commune d'El-Guedid-Algérie. Nos analyses ont permis d'obtenir des informations caractérisant le métier de berger. Nos résultats confirment le rôle déterminant du berger dans la conduite des troupeaux. En effet, 73 % des éleveurs enquêtés ont eu recours au service des bergers. Leurs salaires sont fonctions de la taille du troupeau et du système d'élevage. Ils varient de 15.000 à 70.000 dinars/mois (100 à 466€). Les bergers mobiles perçoivent un salaire supérieur à ceux des sédentaires. Cependant, ils considérèrent que ces salaires ne reflètent pas le travail accompli durant toute l'année (gardiennages des troupeaux, surveillance de nuit des animaux, soins apportés aux animaux, distribution des aliments, etc.). A noter un aspect prospectif essentiel pour revaloriser ce métier : 65 % des enfants de bergers interrogés ne sont pas favorables à exercer ce métier.*

***Mots-clés**. Berger – Enjeux – Métier – Systèmes d'élevage – Salaires – Agropastoralisme.*

I – Introduction

Sheep rearing is a socio-economic activity of major importance. On the economic front, populations in steppe areas depend on it as a source of food and income (Kanoun, 2016). At the national level, livestock contributes on average to 50% of agricultural GDP (Benidir, 2015). Numerically, the steppe region has up to 80% of the national sheep population (DSASI, 2016).

Despite the importance of the various actors in the sheep sector in steppe, the shepherd remains one of the pillars of the small ruminant livestock sector. His expertise in animal husbandry plays a major role in feeding and guarding animals on pasture. His work is therefore of paramount importance for animal protein production and food security.

However, the transformation of the Algerian steppes under the joint influence of economic, territorial, agricultural and environmental policies has made it difficult to recruit shepherds. Indeed, this difficulty is the complex result of many factors and variables. The main forces at stake are changes in herd ownership, employment opportunities in non-pastoral sectors (agriculture, industry), rural depopulation, rapid urbanization, population growth and the deterioration of climate since the 70s and 80s.

The consequences of these various factors for agropastoral farming are numerous (Bessaoud, 2013). First of all, they result in a modification and the emergence of new multidimensional relationships between the different actors in the sector, in particular shepherds and animal owners that consider that the high requirements of the shepherds are not profitable for their investments. Shepherds consider that the working conditions are not encouraging and do not guarantee the maintenance and the sustainable evolution of their careers. This context has led us to question the situation of shepherds and the consequences of changes in herding on the future of this occupation: What is the future of the profession of the shepherd with sociodemographic and territorial changes in the steppe?

Although there is a lack of local references to the profession of shepherd, the text that follows will attempt to present a set of indicators that reflect the evolution of the profession of shepherd and the complexity of the new challenges facing this activity. Therefore, it is interesting to understand the evolution of employability of the small ruminant sector including decent work, quality of life and human resources.

II – Methodology

The El-Guedid area, located northwest of the Djelfa Wilaya between 2.36 ° and 2.79 ° longitude and 34.45 ° and 34.88 ° latitude, is an ideal site to treat the problematic of the study. It is representative of the agro-pastoral steppe territories and has a relevant breeders' potential to study the new issues of the animal production sector, particularly the problems of the availability of shepherds. The number of breeders in the El-Guedid area belonging to the "Ouled Mhani" tribe amounts to 751, or 11% of all the breeders in the Djelfa Wilaya (DSA, 2016). Seven fractions share the territory of this tribe: Ouled Cheikh, Ouled Beidha, Ouled Laouar, Ouled Meriem, Ouled Hana, Ouled Sidi Belgacem, Ouled Ahmed Benbrahim. Each fraction has a space recognized and respected by all right holders. The area covers 115,226 hectares, 90% of which are degraded to very degraded (Kanoun, 2016).

To achieve our objectives, the study favored a qualitative and quantitative method by adopting a participatory process that is based on a systemic approach. This method is based on an exchange and interview process that draws on the disciplinary fields of socio-anthropology and ethnology (Darré *et al.,* 2004; Cialdella *et al.,* 2010).

To better understand the diversity of relationships between the actors (shepherd and animal owner) and the determinants of these relationships, the study sample was constructed on the basis of ethnicity. All the fractions of the tribe "Ouled Mhani" were the subject of this research. Therefore, this choice, which aims at carrying out a study on the current situation on the profession of

shepherds, can only be determined through the combined use of participatory methods and formal surveys. The latter, which concerned 100 observations, were randomly selected at the workplace (farms, pastures and livestock watering). The six individual and group interviews conducted in a semi-directive (with interview guide) and iterative way, targeted resource persons such as young people and breeders belonging to different farming systems (sedentary, semi-transhumant and transhumant). Focus groups and classification matrices are the main techniques used to collect and evaluate qualitative data (Chevalier *et al*., 2008).

III – Results

1. The shepherd of the steppe: a job to encourage

The ambition of our work is to help inform public policies on the issues that weigh on the maintenance of one of the indispensable pastoral activities including the job of shepherd. Indeed, the figures indicate that 73% of livestock farms use the service of shepherds for the management of their sheep flocks. The results showed that transhumant and semi-transhumant herdsmen are most concerned with shepherds. They represent respectively 46% and 33% of the owners. Analyzes also highlighted that sedentary people are concerned by the need to resort to shepherds. They represent 21% of the total number of farms surveyed.

A typology of shepherds was established based on the duration of the guarding of animals. The seasonal shepherds represent 36% of the total shepherds and their age varies between 15 and 70 years. They are mainly recruited by semi-transhumant and sedentary respectively 62% and 47% (Table 1). These herders use this type of shepherd mainly during the school period when the family labor is unavailable. It is the Ouled Beidha and Sidi Belgacem who are recruiting this category of shepherds. The second type is represented by annual shepherds and are on average 47 years old. This type is mainly recruited by sedentary and transhumant pastoralists. These shepherds constitute respectively 47% and 36% of the total shepherds. The last case corresponds to multi-year shepherds. They are between 29 and 63 years old and mainly support transhumant herds. However, the results show that the seasonal type dominates (36%). According to the statements of resource persons, this trend can also be explained by the employment opportunities that have appeared in fattening farms for young rams intended for religious holidays, in particular Aid ElKebir. Indeed, Fig. 1 emphasizes that the seasonal shepherds are recruited by breeders-fatteners and fatteners respectively 45% and 63%. The average length of recruitment rarely exceeds three months / year.

Table 1. Typology of shepherds (%)

	Types of shepherds			
Farming systems	**Seasonal**	**Annual**	**Perennial**	**Total**
Transhumant	12	36	52	100
Semi-transhumant	62	17	21	100
Sedentary	47	47	7	100
Total	**36**	**32**	**32**	**100**

Source: 2018 surveys + our calculations.

However, information from group interviews and surveys revealed that recruiting shepherds is not an easy task for herd owners. Indeed, the results show that 71% of herd owners had difficulty finding a shepherd who meets the requirements of the profession's plurality, particularly a large household size, i.e. the household must be composed of several active members. Data collected on herders' labor indicate three factors that seem to contribute to this scarcity of herders: the inability to accumulate productive capital, the monetarization of fodder resources and the contract (salary).

However, the results showed that shepherds are more demotivated by the low level of their sheep capital endowment during their working period and by wages that do not correspond to the nature of the work performed. These two factors account for nearly 83% of the shepherds' responses. On the other hand, it can be seen that factors related to quality of life and the difficulty of the tasks are not raised by the interviewed shepherds. However, an analysis of the information gathered from young people from sheep herding environments reveals other issues related to this profession. The evaluation of these concerns through a scoring and classification matrix points to other key elements such as social recognition, annual leave, the disappearance of owners' generosity and the difficulty of tasks, etc. (Table 2). However, it should be noted that the respondents (shepherds and young people) unanimously affirm that the accumulation of an animal population and the level of wages are the main attractive opportunities that encourage young people to continue in this profession.

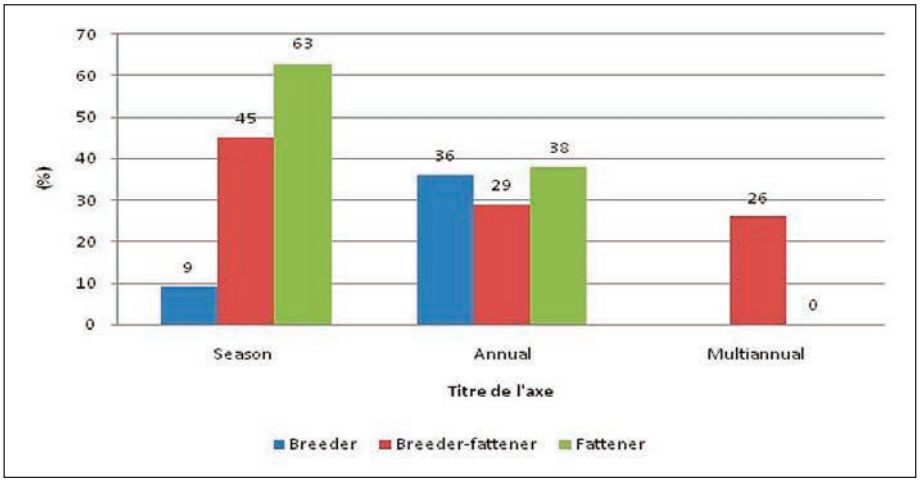

Fig. 1. Recruitment of seasonal shepherds by sheep fatteners.

Table 2. Binding factors cited by young people from different farming systems

Farming systems	Difficulty of tasks	Social recognition	Salary	Annual leave	Disappearance of the generosity of the owners	Accumulation of animals
Transhumant	10	6	9	6	8	10
Semi-transhumant	8	7	9	7	9	10
Sedentary	6	8	10	6	10	10
Total score	24	21	28	19	27	30
Validation by the actors	25/30	20/30	28/30	12/30	26/30	30/30
Rank	4	5	2	6	3	1

Source. 2018 Group Interviews. Comments. The number 10 is considered to be the highest score. The total number of actors is 30 at a rate of 10 per group. Each group corresponds to a breeding system. Rank is established on the basis of validation and not on scores.

2. Remuneration preferences. Salaries that do not reflect the plurality of the profession of shepherd

The analysis of survey's data highlighted the current trend in the remuneration of herders. Salary remuneration seems to be the preference of owner-herders. Indeed, 67% of farmers prefer this option. This form of remuneration is used by sedentary and transhumant livestock herders (Fig. 2). The rest of the farmers opt for remuneration in kind (5 to 7 lambs/10 ewes kept/year); i.e. 25% and only 8% agree on a profit sharing (Table 3). It is the semi-transhumant and transhumant breeders who favor this type of remuneration. Finally, it should be noted that it is the owners who insist on the method of remuneration. The salaries granted vary between 15,000 and 70,000 dinars/month (100 to 466€) and depend on the farming systems and the size of the workforce. Mobile shepherds receive a higher salary than sedentary ones. According to the shepherds' statements, wages do not reflect the plurality of the work done. Especially since an average of 2.5 people are present to help the shepherd carry out the various daily tasks (guarding on the pasture, supplementing animals, night surveillance, watering, cleaning sheepfolds, monitoring of lambing, etc.). This unpaid contribution requires public authorities to take this category of people into account in the design of development programmes in order to motivate them to perpetuate this ancestral profession. Moreover, there is currently no national agreement in Algeria defining the conditions of employment and remuneration of shepherds, unlike most other professions. Indeed, surveys indicate that the dissatisfied are rather relatively young shepherds (20-30 years old).

Table 3. Types of remuneration for animal owners (%)

Types of remuneration	Salary	Kind	Profit
	67	25	8

Source: 2018 surveys + our calculations.

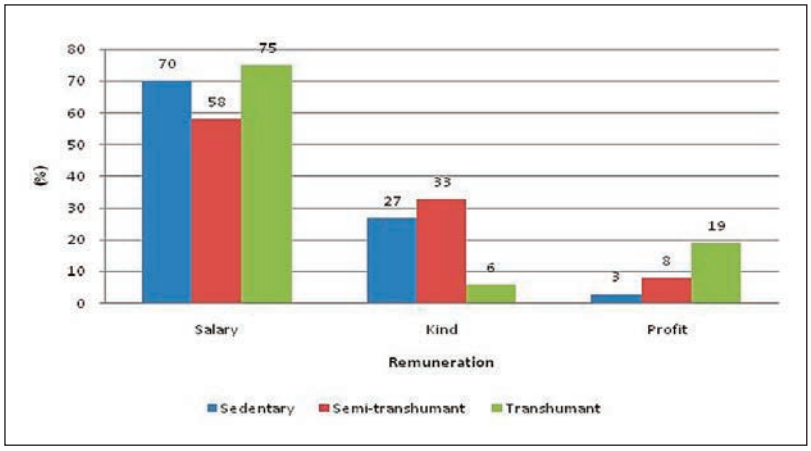

Fig. 2. Types of remuneration of shepherds by livestock system.

IV – Discussion

This work has provided valuable information on a subject for which data are notoriously insufficient. Although the concerns are different, shepherds and their practices are at the crossroads of different issues that contribute to the development and transmission of ancestral knowledge related to sheep herding: the rural exodus to cities that offer employment opportunities and better lives, age-

ing herders, relational problems and generational conflicts. In addition, the deprivation of constituting a number of ewes to generate additional income tends to make shepherds scarce. The monetarization of fodder resources and socio-demographic changes seem to encourage herd owners to adopt contracts that aim to reduce the opportunities for shepherds to change their status. According to Leroy and Gaubert (2000), the disappearance of landless pastoralists is linked to the costs of purchasing land. Indeed, the question of the competent shepherd and the feeling of his rarity are nowadays more and more stated by many steppe herders. This observation is not specific to our study region. Indeed, this phenomenon of a shortage of experienced shepherds is highlighted in the South of France (Lebaudy, 2016).

V – Conclusion

Sustainable development of livestock systems in steppe areas cannot be satisfied with a technical response based essentially on improving herd productivity. The few elements we have gathered from the steppe shepherd reveal that maintaining this trade is essential. Because it is one of the pillars of the sheep sector in steppe environments. Nevertheless, the initial results showed that the issues raised in this study are mainly related to the evolution of contracts that could not allow shepherds to experience a trend towards improving their social and financial conditions. The vast majority of contracts are based on salary remuneration. However, the wages received do not reflect the nature of the work done and limit the accumulation of productive capital (ewe population). These demotivating factors have unfortunately influenced the behaviour of the new generation towards the profession of shepherd. We do not claim to have covered all the aspects related to this profession. To this end, other results will be published on topics covering the work accomplished during the 365 days, the shepherds' knowledge, the shepherds' visions for the development of this profession, training, etc.

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Shepherd school as a tool for the empowerment of the livestock sector

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Abstract. Grazing as a basis for feeding flocks is declining in the European Union. Different problems related to the access of the land and the hardness of the shepherd's work, among others, have meant that the number of farms with this model have dropped. Andalusia (Spain) created its Shepherd School in 2010, an initiative based on collaboration between different entities in the field of livestock and environment. The figure of the shepherd teacher is fundamental for the success of the school: during six weeks, the students carry out practices with them in their farms. In total, there are eighty-four active shepherd teachers, with different local breeds and flocks with different types of production: meat, milk and cheese making. The Shepherds School changes its location in each edition, locating in areas where extensive livestock farming and environmental aspects (protected areas, forests, mountain areas ...) are important. Normally, all the agents of the livestock sector interact in different activities: round tables, workshops with students, group visits, child activities, etc. The media (television, radio and press) regularly visit the school, which is an opportunity to show a sustainable, professional and innovative sector.

Keywords. Training – Shepherds – Ruminant – Andalusia – Society.

L'école de berger comme outil de renforcement du secteur de l'élevage

Résumé. *Le pâturage comme base d'alimentation des troupeaux est en déclin dans l'Union européenne. Les problèmes liés à l'accès à la terre et à la difficulté du travail des bergers, entre autres, ont entraîné une baisse du nombre d'exploitations utilisant ce modèle. L'Andalousie (Espagne) a créé en 2010 son Ecole de bergers, une initiative basée sur la collaboration entre différentes entités dans le domaine de l'élevage et de l'environnement. Le rol du maître berger est fondamentale pour la réussite de l'école: pendant 6 semaines les élèves pratiquent chez eux. Au total, il y a 84 maîtres de berger actifs, avec différentes races autochtones et des troupeaux avec différentes aptitudes: viande, lait et fromage. L'Ecole de bergers change de lieu chaque année, s'installant dans des zones où l'élevage extensif est important et où il existe des lieux à haute valeur environnementale (aires protégées, forêts, zones de montagne...). Normalement, tous les acteurs du secteur élevage de ces sites interagissent dans les différentes activités développées par l'école : tables rondes, ateliers avec des adultes, visites de groupes, activités pour des enfants, etc. Les médias (télévision, radio et presse) visitent régulièrement l'école, ce qui est l'occasion de montrer un secteur durable, professionnel et innovant.*

Mots-clés. *Formation – Bergers – Ruminants – Andalousie – Société.*

I – Project origin

Andalusia created its Shepherd school in 2010 through collaboration between the agrarian and environmental Administration. Since then, a multitude of students has passed through, aimed at settling in or working in the livestock sector in its nine editions. In addition, the livestock sector collaborates intensely in its development through the Associations of breeders, professional organizations, cooperatives and companies, contributing teachers and farmers for the development of the theoretical and practical sessions.

The main objective of the Andalusian shepherd school is to train new farmers, so that they form part of an increasingly competitive and professional sector, combining theoretical knowledge with practical experience on farms. In addition to this general objective, there are others such as: (i) preservation of protected natural areas through the maintenance of extensive livestock, (ii) the conservation of local breeds, (iii) the enhancement of the pastoral products obtained and (iv) the social recognition for the profession of shepherd.

The total training is 540 hours, divided between a theoretical-practical part (300 hours) and another practical part directly with shepherds (240 hours). The participation of shepherds-tutors is essential for the development of this formative activity; the shepherds-tutors are farmers who, after a training process, can receive the students on their farms.

The content of the training is divided into three different parts: (i) a technical and management part: reproduction, genetics, food, health and facilities; (ii) a business part: economic management, marketing and associative actions, and (iii) a third part on the positive role of the shepherd and his flock towards the environmental sustainability of the territory in which it is located (Table 1).

Table 1. Shepherd's school training program

Module	Training program	Hours
Module 1	Shepherd, livestock and grazing	30
Module 2	Livestock facilities and management	30
Module 3	Genetic, reproduction and production	30
Module 4	Feeding, forage production and conservation practices	30
Module 5	Feeding in grazing systems and the role of the shepherd in the maintenance of environmental sustainability	30
Module 6	Healthcare and hygiene of livestock	30
Module 7	Economic management	30
Module 8	Marketing and associations	30
Module 9	Agricultural accounting	30
Module 10	Business relations and risk prevention	30
Module 11	Practices with shepherd teachers	240 (3 periods/80 hours)

The Andalusian shepherd school is itinerant, it changes location every year, but it is always linked to a territory where pastoral livestock is important.

The Andalusian Shepherd School is currently coordinated by the Andalusian Agricultural Research and Training Institute (IFAPA-Junta de Andalucía). This activity is partially financed with funds of the European Union (EAFRD).

II – Results

The school has trained one hundred thirty four students (one hundred two men and thirty-two women), with a rate of incorporation to the livestock activity of around seventy per cent of the participants; mainly as owners of the farm or as workers in family businesses with the aim of carrying out a generational relay.

In addition, 84 shepherds or mentor shepherds have been trained. After the training period (20 hours) they become shepherds-tutors, and then students can do one of the three work experience periods with them in their farms.

There is an important link between the Shepherd's school and the autochthonous breeds present in Andalusia. Andalusia has a high number of local breeds that are used in systems based on grazing,

each of them with its corresponding breeders association. Throughout the training, students know the maximum number of these breeds, through visits to farms, practices with shepherds-tutors who work with some of them or contact with the technicians of the corresponding associations. Generally, each of the editions has been linked to one or some of the breeds present in Andalusia (Table 2).

Table 2. Shepherd's school training program

Edition	Province	Species and major breeds
1	Granada	Sheep, Segureña
2	Málaga	Goat, Malagueña
3	Cádiz	Sheep, Merina Grazalema
		Goat, Payoya
4	Córdoba	Sheep, Merina
		Goat, Florida
5	Almería	Sheep, Segureña
		Goat, Murciano-granadina
6	Granada	Sheep, Lojeña
		Goat, Murciano-granadina
7	Jaén	Sheep, Segureña
8	Sevilla	Sheep, Merino
		Catlle, several breeds (Retinta, Berrenda,...)
		Goat, Florida
9	Málaga	Goat, Payoya
		Sheep, Merina de Grazalema
		Catlle, Pajuna

The aspects linked to the environment are transversal in the development of training, since the beginning is one of the principal axes. In practice, protected areas are visited every year where extensive livestock farming is a traditional activity, such as the Sierra Nevada National and Natural Park, and in this context we interact with environmental agents, managers of these areas and livestock farmers who carry out their work under this environmental framework. Other topics are also covered, such as: wolf and other predators, fire prevention with animals, transhumance...

At present, the market for agri-food products is beginning to differentiate livestock products coming from grazing systems. It is very important to show successful initiatives where companies or individual farmers are marketing their products, and grazing is one of the attributes of sale.

Finally, the social recognition of the role of the shepherd is one of the main objectives. Different activities are carried out here. In one hand, working with schools in areas where the Andalusian shepherd's school is located each year: as an example of last edition, an activity entitled "Shepherd for one day" was carried out with the participation of a total of five hundred children. On the other hand, the media (press, radio and television), who are particulary interested every year in the different activities carried out by the School giving them dissemination. Also from an institutional point of view, it has been chosen as activity of the month in the European Network of Rural Development (2018), and also as Good Practice of the Plans of Rural Development at national level by the Ministry of Agriculture, Fishing and Food of Spain (2019).

III – Future actions

The future of the Andalusian shepherd school is to become a reference in the training of people who want to dedicate to extensive livestock in Andalusia.

The application of new technologies in the pastoral livestock sector is essential to improve, among other things, the quality of life of the shepherd, and because of that becomes an important milestone for future editions.

The differentiation of products from extensive livestock farming, and the diversification of incomes in order to improve farm management will also be promoted in future editions.

The aim is to make this activity more attractive for young people who are interested in starting a pastoral livestock activity.

Finally, it is essential to continue developing activities to publicize the positive aspects that this type of livestock does for society, the possibilities are varied: media, exhibitions, workshops, tastings products.

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Mobile Pastoralism as a retro-innovation for a sustainable future

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Abstract. Mobile pastoralists the world over share a common understanding of the rangelands they live in and a common ability to read these landscapes and be part of it. There is a strong linkage between the maintenance of mobile pastoralism and the protection of rangeland ecosystems. Yet they are also facing unprecedented challenges and the very same pressures that threaten rangelands also threaten their itinerant ways of life. However the voice of the mobile pastoralist is little heard in the cacophony of modern existence and general discord with the natural world. This manuscript, considering the many benefits of mobile pastoralism for rangeland ecosystems, raises suggestions for reflection towards ensuring the needed shift for conservation of mobile pastoralism and rangelands and promotes the International Year of Rangelands and Pastoralists (IYRP) initiative as a global opportunity to increase knowledge and understanding and to develop sustainable actions for conserving these ecosystems and the pastoralists who rely on them.

Keywords. Mobile Pastoralism – Rangelands – Biodiversity – Solutions – IYRP.

Le pastoralisme mobile en tant que rétro-innovation pour un avenir durable

Résumé. *Les pasteurs mobiles du monde entier partagent une compréhension commune des terres de parcours dans lesquelles ils vivent et une capacité commune à lire ces paysages et à en faire partie. Il existe un lien étroit entre le maintien du pastoralisme mobile et la protection des écosystèmes de parcours. Cependant, les pasteurs font également face à des défis sans précédent et les pressions mêmes qui menacent les pâturages menacent également leurs modes de vie itinérants. Cependant, la voix du pasteur mobile est peu écoutée dans la cacophonie de l'existence moderne et de la discorde générale avec le monde naturel. Ce manuscrit, prenant en compte les nombreux avantages du pastoralisme mobile pour les écosystèmes de parcours, suggère des pistes de réflexion pour assurer la transition nécessaire en faveur de la conservation du pastoralisme mobile et des parcours, et promeut l'initiative de l'Année internationale des pâturages et des pasteurs (IYRP) en tant qu'opportunité mondiale d'accroître comprendre et développer des actions durables pour la conservation de ces écosystèmes et des pasteurs qui en dépendent.*

Mots-clés. *Pastoralisme mobile – Pâturages – Biodiversité – Solutions – IYRP.*

I – Introduction

Mobile pastoralism, which is entirely different in essence to intensive livestock production systems, has offered the most sustainable way to make the most of the Earth's rangelands, as it is the case in Mediterranean (Hobbs *et al*., 2008b).

Particularly their mobility and the common property systems they depend on have allowed them to access and conserve forage and water resources that are unevenly distributed and vary over time (Reid *et al*., 2008).

This strong linkage between the maintenance of mobile pastoralism and the protection of rangeland ecosystems has been supported by a growing body of evidence (Yılmaz *et al*., 2019) considering particularly that rangeland landscapes account for between one quarter and one half of the world land area and are dependent on herbivore action for their maintenance which is mostly ensured by pastoral grazing management (McGahey *et al*., 2014).

The examples of this linkage with rangeland biodiversity include but are not limited to: **Generation of spatial heterogeneity** (Coughenour, 2008; Manzano-Baena & Salguero-Herrera, 2018); **Increasing plant species diversity** (Coughenour, 2008); **Promoting diversity of species of different taxonomic groups** (Stein *et al*., 2014; Hevia *et al*., 2013); **Contributing to diversity of wild herbivores** (Coughenour, 2008); **Dispersing seeds** (Manzano & Malo, 2006); **Contributing to soil nutrient cycling** (Coughenour, 2008); **Preventing water pollution** (Mekonnen & Hoekstra, 2012; Manzano-Baena & Salguero-Herrera, 2018); **Contributing to nutrient cycling** (Yılmaz *et al*., 2019); **Preventing wildfires** (Manzano-Baena & Salguero-Herrera, 2018); **Increasing ecosystem resilience** (Coughenour, 2008)**; Maintaining connectivity by creating ecological corridors** (Yılmaz *et al*., 2019, Galvin, 2008; Coughenour, 2008; Worboys *et al*., 2016; Hobbs *et al*., 2008a; Galvin, 2009); **Avoiding isolation and fragmentation of rangeland ecosystems** (Yılmaz *et al*., 2019).

II – Mobile pastoralism, rangelands and historic injustices

In contrast to the traditional view of conservationists that mobile pastoralists are unconcerned of the ecological consequences of their actions (Fernandez-Giménez, 2000), pastoralists themselves bear the highest costs of degraded rangelands (Naimir-Fuller *et al*., 2012).

Their traditional ecological knowledge, along with the strategy of mobility and common property systems, is an important source of information that complements institutionalized conservation and moves towards a more holistic understanding of rangeland ecosystems (Yılmaz *et al*., 2019).

With their traditional ecological knowledge ensuring attentiveness to environmental variability and shifts, mobile pastoralist communities also provide a crucial foundation in researching and responding to climate change and developing geographically-specific adaptation and mitigation strategies (Yılmaz *et al*., 2019; Fernández-Giménez and LeFebre, 2006).

Despite their important role in maintaining and conserving biodiversity and rangelands, mobile pastoralists particularly in the last century have suffered from historic injustices such as, inter alia, grabbing-dispossession (either by expropriation or privatization) of the rangelands and migration routes they use (Yılmaz *et al*., 2019).

These threats, as a main domain of concern, break down the traditional management systems of mobile pastoralists and lead to a weakening of their social-ecological resilience. When their traditional capability to develop sustainable solutions cannot cope with such externally imposed changes, they either abandon the practice completely or diversify and differentiate their management systems, which can lead to the development of responses that in some cases may create conflict with wildlife or institutionalized conservation mechanisms, such as overgrazing (Yılmaz *et al*., 2019).

Unfortunately, not looking the root causes of this problem, the general view among conservationists has been that traditional pastoralism is environmentally harmful and incompatible with nature conservation. Thus conservationists unfortunately contributed to justification of policies that restricts access to rangelands and to transform traditional pastoralism towards intensive livestock production (Yılmaz *et al*., 2019).

III – Gaps and opportunities

Thus despite the need to conserve mobile pastoralism with its many benefits for rangelands, which are one of the most imperilled and the least protected ecosystems on earth, vastly under-represented in the world's protected area system, mobile pastoralism has not been paid enough attention by the global community (Yılmaz *et al*., 2019). Acknowledging the recent endeavours of some global stakeholders such as FAO, unfortunately the responses developed within the diversity of local ac-

tors are mostly not enough recognised and consolidated with those limited number of global actions. This is one of the leading reasons why the knowledge we have of the multiple benefits the practise provides to both humankind and nature, its current situation, the drivers of the threats and the gaps and needs that conservation efforts should address, is still lacking and fragmented. It is also not easy to access the existing information by many of those who would need it most and the lack of efficient transfer of the existing knowledge leads to limited use for actions on the ground (Johnsen *et al*., 2019).

In order to address this need to increase knowledge and understanding and to develop sustainable actions for conserving these unique ecosystems and the pastoralists who rely on them, there is an alliance of many organizations working together towards gaining a United Nations resolution designating an International Year of Rangelands and Pastoralists (IYRP, 2018).

With contributions of this global alliance, the Government of Mongolia has already initiated the official process at the level of Committee on Agriculture (COAG) of FAO. Thus, the proposal for IYRP, to be included in the agenda of the 27th session of COAG in October 2020, has been submitted to COAG secretariat in June 2019 by Government of Mongolia with other supporting countries.

In line with the IYRP initiative, to ensure the needed shift for conservation of mobile pastoralism and rangelands, the following recommendations are strongly suggested:

- Rangelands should be managed in full compliance with the inherent rights of mobile pastoral communities, especially their land and other natural resources-related rights, avoiding policies harming the physical, cultural and spiritual integrity of communities such as forced evictions, sedentarisation and restrictions to their mobility.
- Accordingly national authorities should develop policies, mechanisms and measures, which differentiate between pastoralism and intensive livestock production systems and ensure effective participation of mobile pastoral communities in the governance and management of rangelands. This approach should also recognise the traditional ecological knowledge of mobile pastoralists including traditional common property systems as an integral part of new collaborations going forwards.
- A new understanding, based on respect, dialogue, basic human compassion addressing the root causes of any conflicts including land degradation in rangelands is urgently required in areas where conflict has arisen or has the potential to arise.
- Rangeland authorities should be supported in order to find mutually beneficial solutions regarding governance and management of rangelands, starting with the development of good practice guidelines, fully informed by mobile pastoralist communities.
- The role of mobile pastoralists in maintaining rangeland ecosystems and avoiding fragmentation between wider landscapes needs to be better assessed and recognised by the conservation community and concerned states.
- Scientific community and civil society should contribute to global movement to declare an International Year of Rangelands and Pastoralism by actively engaging and influencing the relevant official authorities in their countries to support the proposal for IYRP submitted to COAG-FAO by the Government of Mongolia.
- Governments should support the proposal for IYRP submitted to COAG-FAO by the Government of Mongolia to be included in the agenda at the regional/block meetings and then vote in favour of the proposal at the 27th session of COAG in October 2020 and finally at the UN General Assembly.

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Approach to the social sustainability of livestock farms

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Abstract. The social dimension of farm sustainability is significantly less documented than the economic and environmental ones. Our objective was to design a framework to analyze it, taking its subjective and context dependent nature into account. The social sustainability was thereby defined from the expression of actors and farmers interviewed in four French contrasted territories, two of which dealt with sheep farming. The different facets of social sustainability identified were organized in seven main axes. The first four are related to farm-focused sustainability: job meaning, work organization, quality of life and health. The last three take into account the embeddedness of farms in a territory and a society: territorial and societal conditions, local and social networks, and contribution to social sustainability of the territory. Our study enlightened the complexity of the social sustainability which refers to different interlocking organization scales (farmers, associates, employees, family, farm, territory), articulates facts and actors' feelings and expectations, deals with both professional and private lives, and relates to the farm's situation but also its dynamics.

Keywords. Work – Quality of life – Health – Networks – Territorial vitality – Livestock.

Approche de la durabilité sociale des exploitations d'élevage

Résumé. *La dimension sociale des exploitations d'élevage est nettement moins documentée que les celles économique et environnementale. Nous proposons un cadre pour l'analyser construit à partir des propos d'une trentaine d'éleveurs et d'autant d'acteurs provenant de quatre petites régions contrastées (montagne, pastorale, polyculture-élevage périurbaine), dont deux avec des élevages ovins, pour tenir compte de sa nature subjective et située. Les différentes facettes identifiées de la durabilité sociale sont organisées en 7 axes. Les quatre premiers sont centrés sur l'exploitation: sens du métier, organisation du travail, qualité de vie et santé. Les trois derniers prennent en compte l'ancrage des exploitations dans un territoire et une société : conditions territoriales et sociétales, réseaux locaux et sociaux et contribution à la durabilité sociale du territoire. Notre étude a mis en lumière la complexité de la durabilité sociale qui fait référence à différentes échelles d'organisations imbriquées (agriculteurs, associés, employés, famille, exploitation, territoire), articule les ressentis, les attentes des acteurs et des faits, traite à la fois de la vie professionnelle et de la vie privée, concerne la situation des exploitations agricoles, mais aussi leur dynamique.*

Mots-clés. *Travail – Qualité de vie – Santé – Réseaux – Vitalité territoriale – Elevage.*

I – Introduction

The concept of sustainable development, widely disseminated in the agricultural sector, led to many assessment methods (Bockstaller *et al.*, 2009) mainly dealing with economic and environmental dimensions. The social dimension of farm sustainability remains much less well documented (Lebacq, 2013), whereas it represents an essential part to understand how livestock farms operate, their territorial and societal roles (Guillaumin *et al.*, 2007), and their evolution facing great socio-economical mutations at local and global scales. With the increase of social expectations concerning livestock activity (animal welfare, products' quality and environment friendly practices), the

drop in the agricultural labor force, the enlargement of structures and the changes in farmers' expectations concerning their work (Dedieu and Serviere, 2012), this social dimension of sustainable development can no longer be ignored. Our objective was to design a framework to analyze it.

II – Method

The social sustainability is a vague and values-laden concept (Bacon *et al.*, 2012), relative to privacy and inner self (Kling *et al.*, 2012). It is socially and culturally constructed in a given context at a given moment (Boogard *et al.*, 2011). To take this subjective and context dependent nature of social sustainability into account, we chose to develop a comprehensive and non-normative approach. The social sustainability was thereby defined from the expression of farmers and territorial actors interviewed in French contrasted territories, in terms of socio-economic and geographical contexts, but also livestock forms and dynamics. The different facets of social sustainability were identified through a thematic analysis of the interviews, and organized in axes considering two points of view on social sustainability: the first expressed at the farm level and second at the territorial scale (Terrier *et al.*, 2010).

III – Results

The designed framework is composed of seven main axes. We will present them, illustrated with the words of sheep farmers of the Massif Central: in the North in Livradois-Forez with a meat sheep farm, in the center in Aveyron with a milk sheep farm and in the South in the Cevennes with a pastoral meat sheep farm.

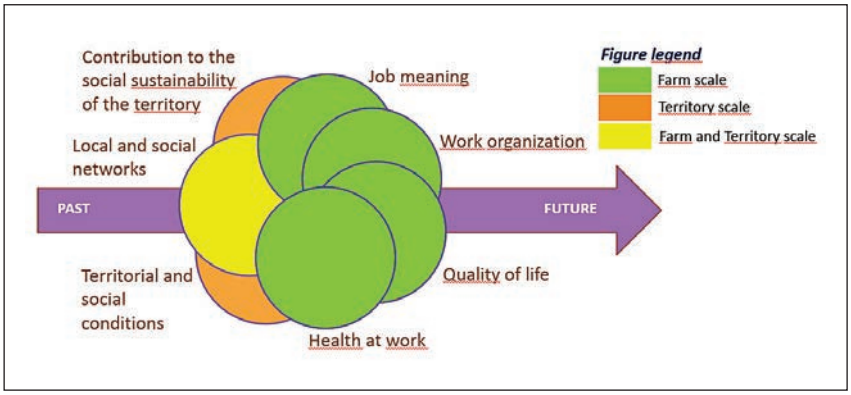

Fig. 1. The 7 axes of social sustainability.

1. The farm focused social sustainability

The first four components of the framework, green on the figure, are related to farm focused social sustainability.

The job meaning refers to the choice to become a farmer, the professional career path with evolution of skills, what farmers seek in their jobs and the recognition they can get from their activity. This component refers to the idea that workers should be proud of their job, experience pleasure at work and evolve during their career paths.

The work organization component brings together different facets relative to working rhythms and duration (length of the working day, workload and distribution over the year), to workforce organization and work productivity. The idea is that the work organization should allow for appropriate efficiency, and be flexible enough to deal with hazards. It should give everyone a suitable place and a reasonable workload.

Quality of life refers to leisure time, the balance between private and professional lives, the living environment and the income. That means that each worker should be able to reserve time for his family, friends or hobbies, live in a suitable environment and get a fair remuneration for his work.

Health at work is about mental and physical well-being and safety. So in order to keep workers healthy, the work should avoid physically painful tasks and offer safe working conditions. Work overload is also psychic (societal pressure, climatic and economic hazards, administrative controls) and can lead to burnout. In the Cevennes, fear of the wolf is growing.

2. The extended to the territory social sustainability

The last three axes take into account the embeddedness of farms in a territory and a society:

A component refers to ***territorial and societal conditions*** that affect the social sustainability of farms. This includes infrastructure (road, internet coverage, slaughterhouse, hospital, school ...), services offered to farmers (such as job opportunities for family members, education and extra-curricular activities for children, heath care for the family), but also the possibility of finding employees, the organization of production sectors, and the proximity of cities. The expectations of local actors are also expressed with regard to livestock and the norms and values recognized by the agricultural profession, which play an important part in farm work and farmer well-being. On a broader scale, the societal expectations in terms of respect for the environment, animal welfare, and products' quality impact the evolution of agricultural models and therefore practices implemented by farmers, disrupting farm work.

A component of the framework is dedicated to the ***contribution of farms to the social sustainability of the territory***. This includes participation in employment and territorial vitality by maintaining a population and services, preserving the landscape and cultural heritage.

The last component refers to the ***local and social networks*** in which farm workers are included. Farmers can belong to several forms of networks (professional, associative, elective and neighborhood). For them these networks mean resources for reinsurance, recognition, mutual help, exchange of practices or knowledge, learning, all of which may be very useful for their activity and well-being and therefore for farm work. Networks' participation also contributes to territorial vitality, which makes this component part of both contributions to social sustainability: the farm focused one and the extended to the territory one.

3. Understand social sustainability in its complexity

The different facets of social sustainability refer to various interlocking organization scales. They concern the farmer himself (well-being, health), his potential associates (agreement) or his employees (safety), his family (living environment), his farm (amount and productivity of work) or his territory (employment). And all these elements are interdependent and interact with each other: for example, social relationships and working time are for example intertwined in an association. Furthermore, they evolve and modify their interactions, which can transform a problematic situation into a favorable compromise or the opposite, such as certain trajectories favoring expansion and investment. Addressing social sustainability cannot be limited to the description of the facts and needs to clarify the relationship between the farmer and his work, his values and objectives. Thus, the very easy quantification of the number of weeks of annual leave does not account for the per-

ception of farmers; one can consider that a week of vacation is enough "*and that he really needs his wife to insist*" *"his wife has to insist to obtain more"*, while others consider that "*two weeks are a minimum*". The situations described in the boxes clearly illustrate the singularity of the situations that lead to highlighting different aspects of social sustainability: workforce and animal reproduction organization for the quality of life in case 1, the desire to work alone with animals in case 2, and understanding difficulties between associates in case 3 with research into social relations.

Box1 : **A milk sheep farm in Aveyron – family association between parents and children**

Parents associated with their two children drive nearly 900 ewes. Flock management was simplified with a single lambing period and no milking from Nov to Feb. Investments were made to facilitate the work (new buildings more functional with concentrate feeders added on the infeed belts and milking machine, hay distributor trailer…). Taking holidays and weekends is easier. "*Now we get to have alternate week-ends: one for the elderly, one for the youngest*". But industry found it difficult to accept a management that stops milking in winter. *"We had to fight so that Roquefort Society agrees to shift the milk of autumn ..."* The expansion, the success of the farm and the installation of both children arouse breeds resentment among neighbors *"It created jealousy to have made these buildings and more ... They didn't like it".*

Box2 : **A specialized meat sheep in Cevennes – farmer alone**

The livestock farmer drives 600 ewes with the help of his retired parents, especially during the lambing period from January to March. He employs a worker in June and July at haying time. Then, he looks after his flock in mountain pasture from August to October. The activity in mountain is almost considered by the livestock farmer as holidays. "*Staying in the mountains during several days, I long for those moments*." In the village, however, relations with neighbors are strained. "*Once, bells sound, then these are flies, then it's the dog barking, it becomes really complicated*." And CAPs controls contribute to add stress while the livestock farmer feels called into questions. "*Well, controls are getting more and more painful. It's my ninth control since I've been installed and the last one went wrong because of the controller".*

Box3 : **A large sheep farm in Livradois-Forez – family association between brothers and father**

Two brothers settled successively on their father's farm after having worked out of agriculture. The structure is large: 1,300 suckler ewes and 24 suckler cows. Father-son relationships are complicated: *" We don't have neither the same objectives not the same visions and are compelled to make compromises... it doesn't satisfy anyone."* For the father, *"going home at 7pm is not an option"*, while the long working days keep the two brothers away from their friends and neighbors: "*When you are invited, I don't go there anymore (because it ends too late), that's what weighs on me*". However, by living there, they can see their children *"every day full of little times"*. They enjoy working in this environment where "*the children are immediately outside to play, without cars, everyone knows each other"*. They contribute to the life of their territory: *"the school called us regularly to check if we would place our children there".*

IV – Conclusion

Our study highlighted the complexity of the social dimension of sustainability. It is necessary to explore different intertwined facets, which deal with facts and feelings, are connected to individual and collective dimensions, are interested in professional and private lives, in order to ultimately understand how their articulation express a singular compromise in movement. The discussion about our framework with farmers, advisors, teachers and local actors confirmed the importance of this social dimension to draw the future of livestock.

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Shepherds in Morocco: the invisible people of sheep and goat systems

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Abstract. In Morocco, the 2013-2017 average of sheep population is 19,290,628 heads and that of goats is 5,817,801. The number of sheep farms is 781,563 and the number of goat farms stands at 301,897. The people responsible for tending these animals are overlooked. Available scientific literature on shepherds is scanty. This paper aims at analyzing the current situation of shepherds and prospects of the shepherding profession. It is based on exploitation of census data and semi-structured interviews with at least five shepherds in each of the following provinces: Agadir Ida-Ou-Tanan, Azilal, Berrechid, Chichaoua, El Kelâa des Sraghna, Essaouira, Khouribga, Rhamna, Safi, Settat, Taroudant, Tata and Youssoufia. According to the 1971 population census, the total number of shepherds was 283,900, over half of which are aged less than 15 years of age. The population of shepherds decreased by 82% between 1971 and the 2014 censuses. The less than 15 years category has disappeared in the 2004 and 2014 censuses. The female contribution to shepherding stands at 17% in the 1971 and 2014 censuses while it reached 25% in the 2004 census. Shepherds form heterogeneous groups in terms of social status, working conditions, remuneration forms and salary levels. The rural young people do not reject to work as shepherds unreasonably, they refuse the conditions associated with the activity. When shepherding is conducted within the family farm it goes unpaid and when it is assumed for others, it results in low pay, long hours, unbearable working conditions and unequal social relations. The shepherding activity needs social and legal recognition, upgrading through professionalization and enhanced attractiveness of the work.

Keywords. Morocco – Shepherd – Sheep – Goats.

Bergers au Maroc : les gens invisibles des systèmes d'élevage ovin et caprin

Résumé. *Au Maroc, la population moyenne d'ovins durant la période 2013-2017 est de 19 290 628 têtes et celle de caprins est de 5 817 801 têtes. Le nombre d'exploitations ayant des ovins s'élève à 781 563 tandis que le nombre d'exploitations avec caprins est estimé à 301 897. Les personnes chargées de ces animaux sont négligées. La littérature scientifique disponible sur les bergers est maigre. Le présent article vise à analyser la situation actuelle des bergers et les perspectives de la profession. Il s'appuie sur l'exploitation des données des recensements et des entretiens semi-structurés avec au moins cinq bergers dans chacune des provinces suivantes Agadir Ida-Ou-Tanan, Azilal, Berrechid, Chichaoua, El Kelâa des Sraghna, Essaouira, Khouribga, Rhamna, Safi, Settat, Taroudant, Tata et Youssoufia. Le recensement de la population de 1971 indiquait un total de 283 900 bergers, dont plus de la moitié avaient moins de 15 ans. La population des bergers a diminué de 82% entre 1971 et 2014. La catégorie des moins de 15 ans a disparu des recensements de 2004 et 2014. La proportion des bergers de sexe féminin s'élève à 17% dans les recensements de 1971 et 2014 et à 25% dans celui de 2004. Les bergers forment des groupes hétérogènes en termes de statut social, de conditions de travail, de formes de rémunération et de niveaux de salaire. Les jeunes ruraux ne refusent pas de travailler comme bergers de manière déraisonnable, ils refusent les conditions associées à l'activité. Lorsque le gardiennage est effectué au sein de la ferme familiale, il est souvent non rémunéré et, lorsque le gardiennage est fait au profit des tiers, la rémunération est faible, durée et conditions difficiles de travail, et des relations sociales inégales. Le métier de berger nécessite une reconnaissance sociale et juridique à travers la professionnalisation et au renforcement de l'attractivité du travail.*

Mots-clés. *Maroc – Berger – Ovin – Caprin*.

I – Introduction

Sheep and goats are an important component of the livestock sector in Morocco. They play an important economic and social role. Their estimated contribution to the country's GDP varies from 1.5% to 2% (Boujenane, 2005). The 2013-2017 average of sheep population is 19,290, 628 heads and that of goats is 5,817,801. The number of sheep farms is 781,563 with an average of 21 sheep and the number of goat farms is 301,897 with an average of 19 goats. Unless kept on-farm or near the house such as the case of some sheep and goat breeds raised indoors, sheep and goats need permanent tending. Even a few ewes or goats will require tending and caring. It is very common in Morocco to observe adult people (men or women) or children (boys and girls) along roadsides with few sheep particularly during the spring season or stubble fields during the summer. Shepherding contracts, family and salaried labor employment cover complex situations and statuses. There are relatively comprehensive works and articles on sheep and goat production systems in Morocco. However, available scientific literature on shepherds is rather scanty and sporadic. Few documents are dedicated to shepherds or contain significant parts on this group. The high territorial diversity of Morocco displays itself in the existence of culturally, linguistically, socio-economically, and spatially differentiated regions. Within such diversity, the study of the situation of shepherds requires an integrative approach. This work is based on to the exploitation of available population censuses data and semi-structured interviews with at least five shepherds in each of the following provinces: Agadir Ida-Ou-Tanan, Azilal, Berrechid, Chichaoua, El Kelâa des Sraghna, Essaouira, Khouribga, Rhamna, Safi, Settat, Taroudant, Tata and Youssoufia. Key issues discussed concerned shepherding arrangements, work conditions and shepherds' views about shepherding.

II – Background

The results of the 1996 General Agricultural Census revealed that Morocco counted 781,563 farms rearing sheep representing 52% of total farms and 71% of all livestock farms. Landless farmers and those with less than one hectare raised more than 16% of the total sheep. Farms between 1 and less than 10 hectares reared 48% of sheep. Farms between 10 and less than 50 hectares raised about 30% of total sheep flock (MADRPM-RGA-1998). Farms with 50 hectares and more hectares kept 6.67% of total sheep population. Goat farms counted 301,897, representing 20% of total number of farms and 27% of livestock farms in the country (MADRPM, 1998). Chentouf (2018) reported that 83% of the national goat flock is reared in small farms of less than five hectares with 46% and 16% located in mountains and Saharan areas, respectively. The heavy reliance on family labor is typical of sheep and goat farms, with more than 80% of the farms use permanent family labor while only 5% of farms engage some permanent salaried labor. The total number of family members working on-farm reaches almost 2 million people (1,955,845) with the ratio of 1.61 per farm. Salaried labor involves 136,593 workers with a ratio of 1.7 per farm.

III – Shepherds in Morocco

In Morocco, the terms '*sareh*', '*amaksa*' and '*rañi*' indicate the shepherd in Arabic dialect, Amazigh speaking communities and classical Arabic respectively. The word '*sarha*' refers to the action of shepherding. The main categories of shepherds in sheep systems include a) the herder-shepherd, b) the family-shepherd other than the herder, c) the associate-shepherd and d) the salaried shepherd. All these types hardly occur in a pure state and vary across regions. The 1971 population census indicated that over half of Morocco's shepherds were children less than 15 years of age with girls contributing 21% to this age group. The second most important age group consisted of shepherds between 15 and 44 years, representing 43.6 of the total population of shepherds with the contribution of the female shepherds standing at 12% (Pascon & Ennaji 1986). Between the 1971

and the 2014 censuses, the population of shepherds decreased by 82%. The most significant decline occurred between the 2004 and the 2014 censuses reaching 66% against a decline of 48% between the 1971 and 2004 censuses. The female contribution to shepherding amounted to 17% in the 1971 and 2014 censuses while it reached 25% in the 2004 census (Table 1).

Table 1. Shepherds by sex according to the 2004 and 2014 population census

Census year	Male	Female	Total
1971	236,000	47,900	283,900
2004	111,375	36,397	147,772
2014	41,454	8,774	50,228

Source : HCP – Results of the general censuses of population and habitat (RGPH).

One significant result of both 2004 and 2014 censuses was the complete disappearance of the less than 15 years category. In the 2014 census, the 15-29 age group represented 58%, followed by the 30-49 age group representing 28.6%. This means that young people engage in shepherding.

Table 2. Shepherds by age groups according to the 2004 and 2014 population censuses

Age group	2004 (N)	2004 (%)	2014 (N)	2014 (%)
15-29	107,183	72.5	29,225	58.2
30-49	26,487	17.9	14,362	28.6
More than 50	14,102	9.6	6,641	13.2

Source : HCP – RGPH 2004, 2014.

Herders, particularly those living in cities, continue to contract associate shepherds among their relatives and their douars of origins. Shepherds searching for animal daily care only, often resort to the '*mouqef'.* The shepherd in the *mouqef* is recognizable by the stick '*âsa*', the hat '*ṭaraza*', a typical backpack '*mozit*' and the type of cloths he wears. Some known *'mouqefs'* include Inezgane in the Souss region and Ain Lehnouch in the Middle Atlas. Brokers ('*smasria'*) in rural souks are well informed on those looking for shepherds, those searching for work and prevailing salary levels. Rhamna and Sraghna continue to have the reputation of suppliers of experienced sheep shepherds. Imintanout, Khénifra and Essaouira are also suppliers of young shepherds. All shepherds are from rural areas with a pastoral background.

Shepherds are responsible for the well-being of all individual animals in the herd, their grazing, watering, walking and movement, relations within the herd, and behavioral conduct. Shepherds organize and supervise the movements of the herd by throwing stones, by throwing the stick, by shouting, by using sounds and phrases animals of the herd are accustomed to. Shepherds know animals' preferred and rejected plants, growth stages of grazed plants and grazed parts in conjunction of forages availability and season.

Levels of salary vary according to the nature of the work. Shepherds who tend the herd from morning to evening receive monthly salaries between 500 and 800 dirhams. Full time, experienced, professional shepherds whose responsibility for the herd is total, be it on-farm or the *âzib* are paid between 1000 and 2100 dirhams/month. A herder – employer in Essaouira (March 2019) declared that his herd is tended by two shepherds one receiving 1200 and the other 1000 dirhams. The cases with 1500 dirhams monthly are many. For this group, shepherds are always housed on-farm or the herder's *'âzib'*; they receive all their food needs, clothes and one animal for *Aid Al Adha.*

IV – Working conditions and social image

In Morocco, working conditions of shepherds vary whether shepherding is conducted in the plains or in mountains, the size and the structure of the herd and the seasonal changes. The extent of the grazing area offered to the herd compels the shepherd to walk long distances on a daily basis. Even when the grazing area is a small fallow field, shepherding necessitates non-stop watching and walking to prevent the animals from trespassing to neighboring cultivated fields. One shepherd from Sidi Bou Othman (Rhamna province) declared walking 12 km daily. Shepherds may have to spend most of their working hours without other people around. While shepherds learn to live with the least comfort and to support the harshness of winter cold and summer heat, their living conditions remain hard particularly during the transhumance and in '*âzib*' stays. Nowadays, the use of the mobile is helping shepherds to stay connected with the rest of the world.

Some shepherds evoked the fact that many prophets, including the prophet Mohammed practiced shepherding. The latter teaches patience, humility, and inner strengths. Shepherds who care for sheep and goats for a proportion of the offspring are positively perceived in Morocco's rural areas. Associate shepherds are known for their trustworthiness, hard work and experience with livestock herding (Pascon and Ennaji, 1986). Looking at the situation of shepherds in Morocco in the light of experiences of countries in the northern side of the Mediterranean revealed substantial shortages with implications for the role and status of shepherds. In Morocco, shepherds as a social category and shepherding as a profession are hardly on the development agenda and public debate. None of the 50 schools providing agriculture and livestock related training offer courses destined to shepherds compared with shepherds' schools in France and Spain. The research and policy efforts for the valorization of Morocco's pastoralism is rather negligible in comparison with the European Union policy.

V – Conclusions

The rural young people do not reject shepherding unreasonably, but they refuse the conditions often associated with the activity. While the family shepherd is denied the respect of the income earner, the salaried shepherd is poorly remunerated. Decision makers need to be innovative in the design and the implementation of policies targeted to shepherds as a specific working category with concrete supportive measures in favor of their qualification, working environment and conditions.

Acknowledgments

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Conclusions

Conclusions of the Meeting

The first Joint Meeting of the FAO-CIHEAM's Networks gathered 136 participants from 15 different countries. Eight (8) keynotes, 30 oral communications and 67 posters were presented, with a general focus on the challenge represented by climate change for the biological components (animals and forage resources), for the farming systems and for the associated value chains. The seminar hosted the final workshop of the international project iSAGE, and a Round Table about pastoralists and extensive livestock farmers, where the social issues of Mediterranean agro-silvo-pastoral systems were discussed. The field trip brought the participants to upland pastoral areas which have suffered from climatic and social changes; current challenges and possible solutions were discussed with local stakeholders.

Bringing together three FAO-CIHEAM subnetworks enabled to explore common subjects such as: (i) the evaluation of forage ecotypes, forage or pasture mixtures and their contribution to feeding systems and product quality; (ii) the multiple functions of animal and plants in the Mediterranean agroecosystems; (iii) the organization of animal and plant production systems or animal products and seeds markets. Contributions dealing with systems and value chains put forward the adaptation and resilience of sheep and goat production systems, identified possible options to improve meat quality and meet consumers' needs and proposed approaches to sustainable pastoralism in order to conserve rangelands' biodiversity. Contributions on animal nutrition tackled promising new feeds containing bioactive compounds, tested methods to identify the impact of nutrition on the quality of animal products (mainly meat), or discussed the technical and organisational aspects involved when the feeding systems change. Contributions focusing on forages and pastures reported the performances of promising forage ecotypes (mainly legumes) in challenging conditions, evaluated alternative forages (mixtures, intercrops…) and tested multicriteria evaluation methods taking into account production, ecological and social issues.

Common interests were identified for a number of crosscutting themes. Participatory research was put forward as an efficient strategy to bring innovation in Mediterranean small ruminant farming systems. A better education and communication about the peculiarities of Mediterranean agro-silvo-pastoral systems was considered as a prerequisite to successful scientific and development projects in the future. A better marketing of sheep and goat products (and services) but also of forage seeds adapted to Mediterranean conditions was pointed as an issue to be solved in order to ensure an impact of our research. Given the limited funds available for research in our areas of study, coordinating our efforts will remain the best way to secure a future for Mediterranean small ruminant systems.

Conclusions de la Réunion

La première réunion conjointe des réseaux FAO-CIHEAM a rassemblé 136 participants provenant de 15 pays différents. Les présentations ont consisté en 8 présentations principales, 30 présentations orales et 67 posters, ayant comme axe général le défi que pose le changement climatique aux composantes biologiques (animaux et ressources fourragères), aux systèmes d'élevage et aux chaînes de valeur associées. La réunion a accueilli l'atelier final du projet international iSAGE, ainsi qu'une table ronde à propos des pastoralistes et des éleveurs en extensif, où les questions sociales des systèmes agrosylvopastoraux méditerranéens ont fait l'objet de débat. La sortie de terrain a conduit les participants jusqu'aux hautes terres pastorales ayant subi des mutations climatiques et sociales, où les défis actuels et les solutions possibles ont été examinés avec les acteurs locaux.

Le fait de rassembler trois sous-réseaux FAO-CIHEAM a permis d'explorer des problématiques communes telles que : (i) l'évaluation des écotypes fourragers, des mélanges pour fourrages ou pâturages et leur contribution aux systèmes d'alimentation animale et à la qualité des produits ; (ii) les multiples fonctions entre animaux et plantes dans les agroécosystèmes méditerranéens ; (iii) l'organisation des filières de production animale et végétale ou des marchés de produits animaux et de semences. Les contributions axées sur les systèmes et les chaînes de valeur ont mis en avant l'adaptation et la résilience des systèmes de production ovins et caprins, ont identifié des options possibles pour améliorer la qualité de la viande et pour répondre aux exigences des consommateurs, et ont proposé des approches pour un pastoralisme durable afin de conserver la biodiversité des parcours. Les contributions sur la nutrition animale ont abordé des aliments nouveaux et prometteurs pour bétail contenant des composés bioactifs, ont testé des méthodes pour identifier l'impact de la nutrition sur la qualité des produits animaux (notamment la viande), ont discuté les aspects techniques et organisationnels qui interviennent lorsque change le système d'alimentation. Les contributions focalisées sur les pâturages et fourrages ont rapporté les performances d'écotypes fourragers prometteurs (surtout légumineuses) sous conditions contraignantes, ont évalué les fourrages alternatifs (mélanges, cultures intercalaires, …) et ont testé des méthodes d'évaluation multicritères tenant compte de la production et des enjeux écologiques et sociaux.

Des centres d'intérêt communs ont été identifiés pour plusieurs thématiques intersectorielles. La recherche participative a été mise en avant en tant que stratégie efficiente pour porter l'innovation jusqu'aux systèmes méditerranéens d'élevage de petits ruminants. Un enseignement et une communication plus poussés concernant les particularités des systèmes agrosylvopastoraux méditerranéens sont considérés comme condition préalable pour assurer le succès des projets scientifiques et des projets de développement à venir. Une meilleure commercialisation des produits (et services) ovins et caprins mais aussi des semences fourragères adaptées aux conditions méditerranéennes a été signalée comme une question à résoudre afin d'assurer les retombées de notre recherche. Étant donné les fonds limités disponibles pour la recherche dans nos domaines d'étude, la coordination de nos efforts demeurera la meilleure manière d'assurer le futur des systèmes méditerranéens de petits ruminants.

Programme

PROGRAMME

DAY 1 23RD OCTOBER

8:30 – 9:00	*Registration*
9:00 – 9:30	**Opening by authorities**
9:30 – 10:00	**INTRODUCTORY CONFERENCE: Moroccan production systems, rangelands and forages**. *A. Keli, M. Mounsif (ENA Meknés, Morocco), M. Chentouf (INRA Morocco) and A. Araba (IAV Hassan II, Morocco)*
10:00 – 11:15	**PLENARY SESSION 1: WHAT PRODUCTION SYSTEMS AND PRODUCT CHAINS TO MEET THE SOCIETAL DEMAND?** *Chairperson: M. Chentouf (INRA, Morocco)* **- Keynote presentation: Resilient and efficient small ruminant value chains in the Mediterranean basin: Challenges and opportunities from societal and consumers' needs.** *R. Zanoli (Univ. Politechnica delle Marche, Italy)* **- Keynote presentation: Impact of feed quality on animal health and food safety.** *M. Bengoumi (FAO-Subregional Office for North Africa)*
11:15 – 11:45	*Coffee break*
11:45 – 13:15	**- Short oral presentations:** **S1-35 – Diversité des systèmes de production agricole dans le massif forestier du Boutaleb, Algérie.** *H. Sahraoui (Univ. of Setif 1, Algeria)* **S1-44 – A collaborative multi-stake holder analysis of the sheep and goats sector challenges.** *A. Belanche (CSIC, Spain)* **S1-20 – Factors influencing sheep farmer attitudes towards breeding tools across Mediterranean local breeds.** *D. Martín-Collado (CITA, Spain)* **S1-30 – Flavored Moroccan goat cheese prepared with rosemary (*Rosmarinus officinalis* L.) and white wormwood (*Artemisia herba-alba* Asso) essential oils: Sensory profile and physicochemical properties.** *Y. Noutfia (INRA, Morocco)* **S1-27 – Dietary inclusion of whole pomegranate by-product to improve oxidative stability of lamb meat.** *A. Natalello (Univ. of Catania, Italy)* **- Posters focus** *by session chair* **- Open discussion**
13:15 – 14: 30	*Lunch*
14: 30 – 17:30	**PARALLEL SESSION 1: NUTRITIONAL STRATEGIES TO IMPROVE SHEEP AND GOAT ADAPTATION AND PRODUCTION EFFICIENCY** *Chairperson : M. Joy (CITA, Spain)* **- Key note presentation: Smart feeding for improved performances and meat and milk quality of small ruminants.** *B. Valenti, (Univ. of Perugia, Italy) , H. Ben Salem (IRESA, Tunisia)* **- Short oral presentations:** **P1-01 – Replacement of soybean meal with lupine in barbarin lamb diet: Effect on intake, digestion, blood metabolites and growth**. *S. Abidi (INRAT, Tunisia)* **P1-03 – *In vitro* fermentation and acidification potential of several carbohydrates sources used in concentrate-based diets for growing ruminants.** *Z. Amanzougarene (Univ. Zaragoza-CITA, Spain)* **P1-09 – Effects of ensiled sugar-beet pulp incorporation in the diet on performance of lamb fattening.** *M. Benbati (INRA, Morocco)* **P1-14 – Halophytes and grass pea as alternative fodder resources for rearing lambs on saline area: The case of Kerkennah archipelago.** *M. Friha (ISA de Chott-Mariem, Tunisia)*

	P1-15 – Feed efficiency of barn-dried hay obtained in a sustainable goat farming system (Patuchev) for dairy goats. *S. Giger-Reverdin (UMR INRA-AgroParisTech MoSAR, France)*
	15:45 – 16:15: Coffee break
	- Short oral presentations: **P1-18 – Characterization of goat neonatal mortality in northern Morocco and impact of colostrum supplementation.** *N. Hamidallah (Univ. Hassan Premier Settat, Morocco)* **P1-27 – Nutritional and production aspects of partially or totally replacement of berseem hay by cassava in ewes feeding.** *A.S. Morsy (Arid lands Cultivation Research Institute, Egypt)* **P1-28 – Garlic (*Allium sativum* L.) in ruminant nutrition: Chemical composition, antioxidant and antimicrobial activities and *in vitro* effect on digestion in sheep.** *N. Moujahed (INAT, Tunisia)* **- Posters focus** *by session chair* **- Open discussion**
14:30 – 17:30	**PARALLEL SESSION 2: PROMISING FORAGE RESOURCES FOR MEDITERRANEAN PRODUCTION SYSTEMS** *Chairperson: M. Jouven (Montpellier SupAgro, France)* **- Key note presentation: Promising forage resources for production systems in Mediterranean areas.** *L. Peccetti (CREA, Italy)* **- Short oral presentations:** **P2-07 – Performance of local populations of *Medicago truncatula*, *M. laciniata* and *M. minima* collected in the Algerian steppe areas.** *A. Chebouti (INRAA, Algeria)* **P2-08 – Influence of altitude and seasons on the forage quality of *Prosopis juliflora* shrubs.** *M. El-Morsy (Desert Research Center, Egypt)* **P2-10 – Developing annual cereal-legume mixtures in dairy goat farms in South-West of France, to improve protein self-sufficiency and reduce feeding costs.** *J. Jost (Institut de l'Élévage, France)*
	15:45 – 16:15: Coffee break
	- Short oral presentations **P2-11 – Biomass production of different annual cereal-legume intercrops under Moroccan conditions.** *R. Kallida (INRA, Morocco)* **P2-20 – Influence of different *Rhizobium sullae* strains and soil fertility on the agronomic performance of Sulla (*Sulla coronaria* L.).** *M. Sitzia (AGRIS Sardegna, Italy)* **S3-13 – Comparative evaluation of winter forage legumes under Mediterranean rain-fed conditions.** *I. Hadjigeorgiou (Agricultural Univ. of Athens, Greece)* **- Posters focus** *by session chair* **- Open discussion**
14:30 – 18:15	**PARALLEL WORKSHOP OF THE ISAGE PROJECT** Presentation of main results by project team members, flash presentations from participants and open discussion (see separate programme).

DAY 2: 24TH OCTOBER

Full day field trip to Middle Atlas area to visit small ruminant productions systems under grazing conditions.

DAY 3: 25TH OCTOBER

9:00 – 11:15	**PLENARY SESSION 2: MEETING THE CHALLENGE OF CLIMATE CHANGE IN MEDITERRANEAN AGRO-PASTORAL SYSTEMS.** *Chairperson: M. Louhaichi (ICARDA, Jordan)* **Key note presentation: Climate change impacts on Mediterranean small ruminant production systems and mitigation options.** *A. del Prado (BC3, Spain)* **- Short oral presentations:** **S2-03 – Rehabilitation of Algerian rangelands : effects of *Atriplex canescens* plantation on biodiversity, soil physico-chemical parameters and soil surface elements.** *F. Amghar (Univ. M'Hamed Bougara Boumerdes, Algeria)* **S1-08 – The prospects of pastoral sheep and goat dairy systems in the Mediterranean to cope with global changing: An analysis from the Corsican case.** *J.P. Dubeuf (INRA, France)* **S2-05 – Dynamics of livestock farming systems and adaptation strategies to climate and socio-economic changes in the Sétifienne semi-arid zone (Algeria).** *M. Benidir (INRAA, Algeria)* **S2-08 – Holistic Management: An approach to increase pasture sustainability and mitigate climate changes effects.** *G. Moreno (Univ. Extremadura, Spain)* **S2-11 – Evolution and transformation dynamics of rangeland in Moroccan north Atlasic plains and plateaux: Rhamna's case.** *M. El Koudrim (INRA, Morocco)* **S2-17 – Phytomass estimation of Moroccan Rangeland using Sentinel-2 satellite indices and *in situ* biomass measurements.** *H. Mahyou (INRA, Morocco)* **S2-19 – Ameliorating soil acidity improves the resilience of pasture production under extended drought.** *M. Norton (Wagga Wagga Agricultural Institute, Australia)* **- Posters focus** *by session chair* **- Open discussion**
11:15 –11:45	*Coffee break*
11:45 – 13:00	**PLENARY SESSION 3: IMPROVE THE CONTRIBUTION OF GRAZED AND CROPPED FORAGE IN THE FEEDING SYSTEMS** *Chairperson: M. Mounsif (ENA Meknès, Morocco)* **Keynote presentation: Improving the use of grazed forage in Mediterranean ruminant systems: issues, options and perspectives.** *M. Jouven (AgroSup Montpellier, France), A. Franca (CNR-ISPAAM, Italy),and I. Casasús (CITA, Spain)* **Keynote presentation: Management and restoration of pastures and rangelands in the Mediterranean basin from the Northern and the Southern perspective.** *Y. Pueyo (IPE-CSIC, Spain) and A. El Aich (IAV Hassan II, Morocco)*
13:00 – 14:00	*Lunch*
14:00 – 15:45	**PLENARY SESSION 3 (CONT.): IMPROVE THE CONTRIBUTION OF GRAZED AND CROPPED FORAGE IN THE FEEDING SYSTEMS** **- Short oral presentations:** **S3-28 – Extending forage production using mixtures in a Mediterranean rainfed environment.** *C. Porqueddu (CNR-ISPAAM, Italy)* **S3-29 – Intensive rotational grazing for small ruminant feeding in Mediterranean areas.** *R. Primi (Univ. of Tuscia, Italy)* **S3-14 – The Northwestern meadows of Tunisia: Feed source to efficiently produce a healthy sheep meat.** *H. Hajji (IRA Médenine, Tunisia)* **S3-16 – Fertilization ameliorates the production of natural wet meadows in the oriental Atlas mountain of Morocco: The case of Imilchil region.** *A. Homrani Bakali (INRA, Morocco)*

	S3-19 – Developing a toolbox for rangeland restoration/rehabilitation in arid environments. *M. Louhaichi (ICARDA, Jordan)* **S3-22 – Analysis of forage balances in the Djelfa region from 2001-2015. What is the place of the pastoral and cultivated resources?** *M. Kanoun (INRAA, Algeria)* **S3-18 – Autonomy and forage grasses in goat farming of western France: First results of a sociological survey.** *B. Leroux (GRESCO/Univ. of Poitiers, France)* **S3-24 – Different forms of Crop-Livestock Integration. Analysis in the South of France.** *M. Napoléone (INRA, UMR Selmet, France)* **- Posters focus** *by session chair* **- Open discussion**
15:45 – 16:15	*Coffee break*
16:15 – 17:45	**ROUND TABLE ON PASTORALISTS AND EXTENSIVE LIVESTOCK FARMERS** *Chairperson M. Bengoumi (FAO-Subregional Office for North Africa)* **Panellists:** - *M. Bengoumi (FAO)*. Improving governance of pastoral lands (FAO Voluntary guidelines) - *M. Mounsif (ENA Morocco)*. Pastoral livestock sector in Morocco - S. *Fagouri (Arab Network of Pastoralists, Morocco)*. Roles of pastoral networks for sustainable rangeland management - *M. Kanoun (INRA Algeria)*. Sheep shepherds in the Algerian agro-pastoral steppes: Which reading? - *F.A. Ruiz Morales (IFAPA, Spain)*. Shepherd school as a tool for the empowerment of the livestock sector - *J. Lasseur (INRA, France)*. Approach to the social sustainability of livestock farms - *E. Yilmaz (Yolda Initiative, Turkey)*. Mobile Pastoralism as a retro-innovation for a sustainable future **Open discussion**
17:45 – 18:15	**CLOSING SESSION** Synthesis of the Meeting, closing ceremony and prizes.

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Centre International de Hautes Etudes Agronomiques Méditerranéennes

International Centre for Advanced Mediterranean Agronomic Studies

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Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas

Edited by:
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The 1st Joint Meeting of the FAO-CIHEAM Network on Sheep and Goats (Subnetworks on Nutrition and Production Systems) and the FAO-CIHEAM Subnetwork on Mediterranean Pastures gathered more than 130 participants from 15 different countries in Meknes (Morocco), from 23 to 25 October 2019. The objective of the Meeting was to encourage the participation of and interaction between scientists, technicians and professionals to improve small ruminant productivity and to enhance the management of pastoral and forage resources in Mediterranean countries. The Meeting was devoted to present and exchange research advances on: (i) questions of common interest for the Networks (what production systems and value chains to meet the societal demand?, how to meet the challenge of climate change in Mediterranean agro-pastoral systems?, and how to improve the contribution of grazed and cropped forages in the feeding systems?); (ii) specific issues of interest for the Subnetworks (nutritional strategies to improve adaptation and production efficiency, promising forage resources for Mediterranean production systems); and (iii) the results from the 4-years research EU project iSAGE-Innovation for Sustainable Sheep and Goat production in Europe, dealt with in a specific Workshop. The Meeting was closed with a round table on pastoralists and extensive breeders, to present views and experiences in different countries to preserve and promote pastoral systems. This publication gathers the full articles of most of the presentations (keynotes, orals and posters) of the Meeting, providing a sample of the research efforts and scientific advances responding to the need to improve the efficiency and the resilience of Mediterranean forage resources and small ruminant production to cope with regional and global challenges.

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