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Innovation in Tunisian citrus fruit farming

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1. General introduction

In the work of Robert Solow[1] and his model highlighting the pivotal role of technical progress in economic growth, the question of technological innovation remains of prime importance whenever we consider long-term dynamics. In addition to sharing the productivity gains obtained in this way, technical progress and the associated efficiency level have also established competitive advantages which Michael Porter identified at both the sectorial and international scale (Porter M., 1993). Competitive advantage is based on the capacity to create an environment conducive to technological innovation facilitating a reduction in costs or an improved response to demand[2].

The question of technological innovation is the burning issue of the moment. The general programme of which the Sustainmed[3] project is a part offers a clear demonstration of this as it focuses on the bio-economy based on knowledge[4]. Within the framework of this project, we have endeavoured to incorporate this vision of innovation in the analysis of value chain competitiveness[5].

In light of the magnitude of the question examined and the lack of literature, we chose to examine one country and one value chain in detail: Tunisian citrus fruit. Our study is divided into three complementary sections: the first positions the Tunisian citrus fruit value chain on the international market and describes its originality with a view to hierarchizing the technological

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[1] Nobel Prize winner for economics in 1987; *A Contribution to the Theory of Economic Growth, 1956*

[2] With regard to a nation, Michael Porter identified four parameters the combination of which determines the efficiency of companies. The first parameter is the capacity to generate “specialised factors”: scientific competencies, know-how, research centres, etc. The second is the capacity to adapt to customer requirements. The third to call on industries both upstream and downstream which also demonstrate a good performance: due to their interdependence, the success of one stimulates success among the others and the investments made by one serve the others. Finally, the forth is the intensity of domestic rivalries between competing firms with Marshall’s notion of “industrial district” where firms in the same sector stimulate and support one another. None of this is based on chance or solely on production costs: competitive advantage is generated through the strategic choices of the companies and states. *Alternatives Economiques* no. 111 - November 1993

[3] Sustainmed: Sustainable agri-food systems and rural development in the Mediterranean Partner Countries

[4] KBBE: Knowledge-Based Bio-Economy

[5] Task W4T5 - Innovation and food supply: with evident synergies with the first three tasks in WP4, Task W4T5 will establish a diagnosis of innovative chains connected with commodity value chains produced and identify potential actions to improve the competitiveness of these chains. This task will be providing research on the innovation process through actors of the value chain, which generate and transfer innovations. The focus will be on the social dimensions of the innovation process that can be represented as a collective process, based on the interaction between actors, and on the role of public policies and institutions in the production of knowledge and its dissemination, in the networking of actors involved in the process of innovation. In connection with the value chains studied in the previous WP4’s tasks, the task will (i) characterise the technological trajectories for some value chains in selected countries; (ii) characterize the public and private environment and support to innovation; (iii) study the behaviour of firms for innovation and the role of their partners (suppliers / customers). Commodity chains/country couples will be selected to study the transfer of technology between both sides of the Mediterranean Sea. Selected chains will also include some examples of chains oriented to the local market.

factors studied in the second part. This second section identifies and examines the technological factors of strategic importance to the international competitiveness of this value chain including the risk of major biological crisis, varietal dynamics, biological combat and reduced use of pesticides. This analysis of the upstream section of the innovation chain (cf. infra) is complemented by a test designed to understand fruit growers' behaviour in adopting technological innovations, as it is at this stage that the factors of technological competitiveness are expressed. In this third section, we decided not to present a long catalogue of descriptive statistics for the answers concerning technological innovation. The fact that it is impossible to compare these data over time limited the qualitative assessment of the results. Instead, we decided to establish a typology of citrus fruit growers with regard to sectorial technological innovation by using the most efficient data analysis method from this standpoint: ascending hierarchical classification (Ward's method). This work generated some original results with regard to the literature concerning the adoption of innovation by farmers.

2. Understanding innovation in Tunisian citrus fruit farming

2.1 Theoretical and methodological guidelines

The theoretical references concerning this particular field of economics are numerous, diverse and increasing rapidly (Martin Ben R., 2012). More particularly, they have been renewed with the approaches drawn from industrial and innovation economics within the framework of evolutionist theory. The perception of this issue among rural economists has only developed relatively recently and remains attached to what should be qualified as the socio-economic conditions of adopting innovations in agriculture. The main elements of the evolution of this approach concern a more systemic and less linear vision of innovation in this sector, thereby taking account of the wide diversity of situations, often located in a single territory and benefitting from the accumulation of farmers' knowledge and know-how, hence the new acronym AKIS: *Agricultural knowledge and innovation systems* (Bergeret and Krijn, 2012). However, the objectives assigned to what was long referred to as "rural development" or "extension" remain the focus of political concerns, i.e. feeding a population which is estimated to grow to nine billion people in 2050 while improving labour productivity and sectorial competitiveness in a changing world.

In the study that we conducted, we chose the reference to the approach in terms of innovation value chain. The concept of innovation value chain is an application of the value chain approach within the framework of the General System Theory to a second level of analysis. It simply involves bringing a product value chain into relation with a set of innovation value chains which contribute (in a systemic vision) to the technological and competitive dynamics of an agricultural or industrial sector. We developed this tool in the studies of the technological choices relating to the wine value chain (Montaigne 1992, 1996, 2012). This approach is perfectly in line with the evolutionist vision of innovation within industrial economics, characterised by the endogenisation of technological dynamics in economic analysis (Dosi et al., 1988).

We defined the innovation value chain as "the set of firms and private or public organisations contributing to the process of creating a technology, or in other words to the solving of a technological paradigm, to its technical economic assessment in the firms concerned and thus to the definition of a technological orientation understood as the set of technological orientations of the elementary firms."

This concept allows a field of observation to be defined which is relevant in an applied case study. It justifies an economist studying technology as an intrinsic limit to the technological paradigm[6]. It studies the interactions between the players in a sectorial study. Within the limits of a technological orientation, it separates what is a matter for firms upstream and downstream, for the technological paradigm itself and for the structure of the innovation value chain. It encourages us to list the specific management and decision-making criteria adopted by the firms and justifies studying the strategies of the key links in the upstream and downstream product value chains while also shedding light on the applied research policy.

[6]The concept of technological paradigm can often be approached or characterised by that of a research programme with different levels of generality or complexity.

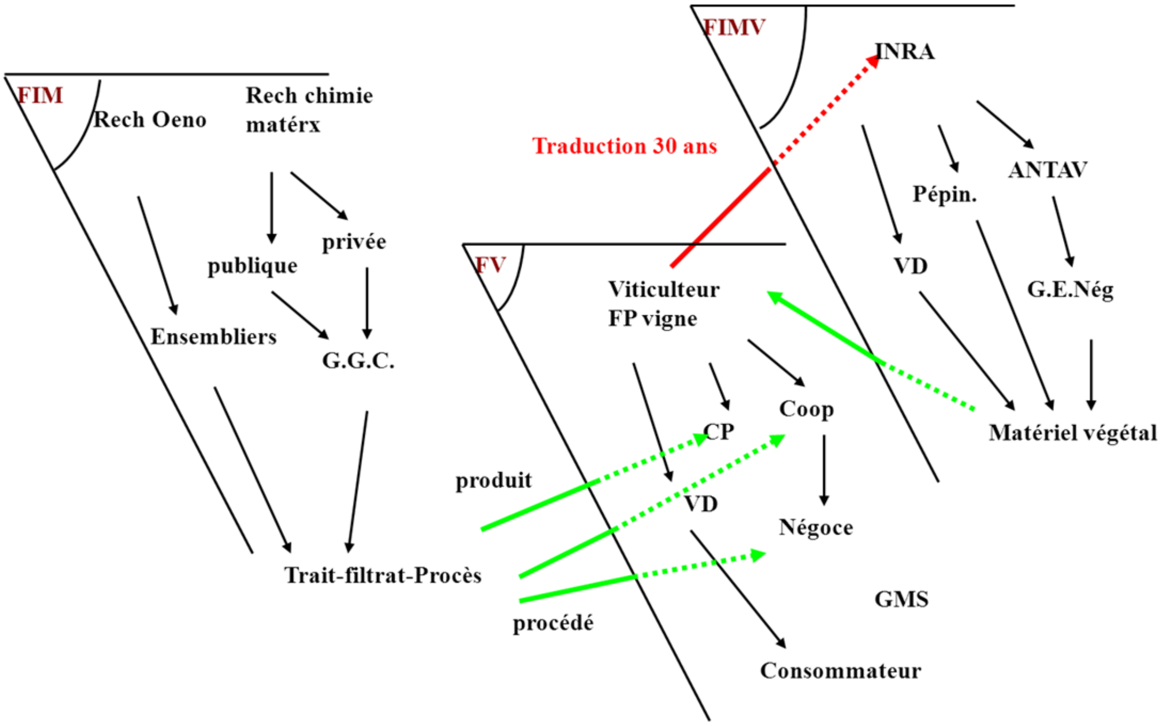

Figure 1 – Illustration of the concept of an innovation value chain combined with a product value chain

Although these works were developed and applied to the wine value chain, they can, in practice, also be transposed unchanged to the entire agricultural value chain and in particular to perennial plants.

We therefore examined the means of transforming the citrus fruit value chain in Tunisia by taking account of the results of current research and their importance in terms of competitiveness.

2.2 The two focuses of the study:

2.2.1 The questions and the players

The first stage of our work was to understand the technical conditions of citrus farming, paying particular attention to the Tunisian context. In doing this, we enjoyed the help of the specialists in Montpellier and the literature already available. We then met the research directors (INAT and INRAT[7]) and the experimentation directors in this field in Tunisia, in particular the Director and technicians of the CTA[8]. The EuromedCitrusNet programme enabled us to list all the entities and the programmes in progress[9].

Research work follows a number of paths, some of which are relatively traditional in the field of improving production: improving rootstock for increased efficiency in the use of water and mineral elements, varietal improvement, farming techniques, micro-grafting and techniques for fighting parasites, including biological control. Our aim was not to study all the research programmes but to assess those which underline the risks or concern important economic objectives for the value chain. In the end, we adopted two: the issue of rootstock with regard to tristeza and the difficulties associated with implementing biological control. In the first case, we took into account the risk of the orchard disappearing in its entirety while in the second case, we examined the commercial importance of a significant reduction in the use of pesticides and in their residues.

2.2.2 A survey of the "recipients"

The second phase of our work involved ensuring a better understanding of the innovative behaviours of Tunisian citrus fruit farmers. To this end, we conducted a qualitative and quantitative survey of a sample of 161 citrus fruit farmers in the main traditional production areas such as Cap Bon and in regions where new plantations could be observed, such as Dega, Kairouan and Jendouba. We observed the traditional characteristics of the farmers and their farms before matching these with the behaviour of adopting innovations.

By combining the characteristics of the farmer and his farm with variables representing the adoption of innovations, we suggested a typology of citrus fruit farmers and their behaviour.

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[7] Institut National Agronomique de Tunis, Institut National de la Recherche Agronomique de Tunisie

[8] Centre Technique des Agrumes, 8099 ZaouietJedidi – Beni Khalled - B.P.: No. 318 Tunisia

[9] Laajimi Abderraouf, Ben Mimoun Mehdi, 2007

3. The particularity of the citrus fruit value chain in the global market and innovation

In this section, we explore the workings of the Tunisian citrus fruit value chain with a view to deriving the characteristics demonstrating the importance of the choice of varietal innovation and thus to studying the objectives.

Tunisia is a very small producer of citrus fruits. Although production has grown by 60% over 10 years, it nevertheless totalled only 360 thousand tonnes in 2011/2012, i.e. 1.7% of Mediterranean production which in turn accounts for only 20% of global production. The production of citrus fruits covers a large period of six months running from November to April. With the new varieties of clementines, navel oranges and tangerines introduced in 1995, the production period was extended to run from October to May, representing a total production period covering eight months.

The main varieties of citrus fruit farmed in Tunisia are as follows:

- Oranges: Maltese (1/2 blood, early Bokhobza, late Barlerin, blonde); navels (Thompson, Washington); Double Fine and Double Fine improved; Sweet (Maltese, Meski, Ansli); Chémi;
- clementines: Cassar;
- mandarins: Arbi; tangerines;
- lemons: Eurêka, Lunari, Arbi;
- various varieties: pomelo (Marsh Seedless, Star Ruby); limes (sweet lime, acid lime, Bearss lime), citron, etc.

The surface area dedicated to citrus fruits totalled 21,000 ha in 2010, i.e. more than 0.4% of total useful farming land in Tunisia. Three-quarters of orchards are located in Cap Bon. Cap Bon remains the main production zone, accounting for almost 74% of total citrus farming area. The structure of Tunisian orange groves has changed and we not only observe an increase in total surface area but also an increase in the number of farmers, with a majority of small-scale farms (32% of the surface area is occupied by small-scale farms). The number of trees has increased by 26% since 1999 (CTA, 2009).

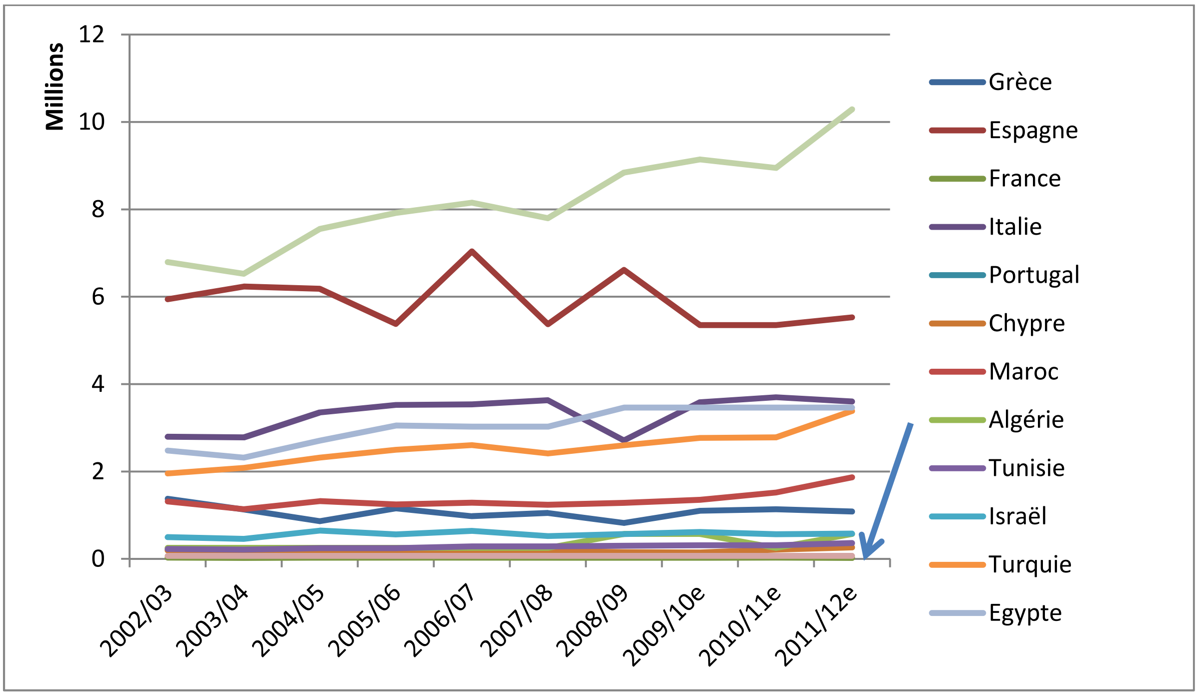
The citrus farming sector in Tunisia is highly strategic in Tunisian agriculture as it provides income for more than 11,600 producers and more than 18,000 families. It accounts for casual labour estimated at 3 million man days per year (CTA, 2009).

On average, Tunisia exports 25 thousand tonnes of citrus fruits, representing 7% of its production. However, these exports largely consist of the Maltese variety with almost 80% of production intended for export, primarily to France. For the crop year 2011/2012, exports of oranges per variety were composed of 95.2% Maltese, 2.8% Navel, 1.4% Valencia and 0.6% others.

With regard to technical innovation, the main characteristics of this citrus farming draw our attention to a number of essential points: first, there is the issue of variety and the importance of the Maltese variety as well as the privileged relations with France on this market. This variety of orange is marketed as a high-quality product at a higher price than other categories. In February 2013, the Marseille border price of Maltese oranges reached one and a half times that of Spanish navels. French consumers appreciate the ease of peeling, the balance of sweetness and acidity, its juice content and the lack of pips. The flesh is very juicy, very aromatic and slightly acidic. The red colour is spread throughout the inside of the fruit with varying levels of stripes depending on the farming conditions (Gifruits).

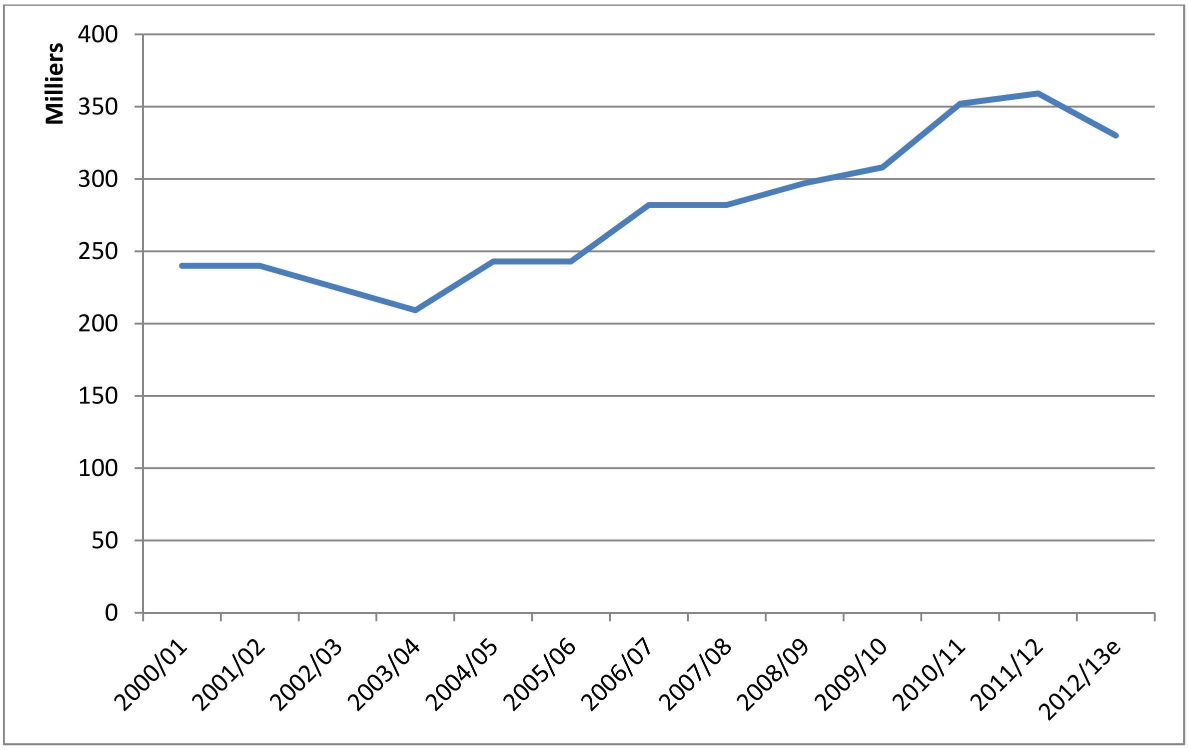
Nevertheless, the supply of citrus fruits is becoming more diversified. The Maltese orange now faces competition from the Thomson variety as well from as clementines, although these are almost all marketed locally. The prices are relatively high, encouraging producers to devote more resources to them (land, water, etc.). The development of domestic demand should be analysed from a qualitative point of view.

Figure 2 – Citrus fruit production in the Mediterranean basin (million tonnes)



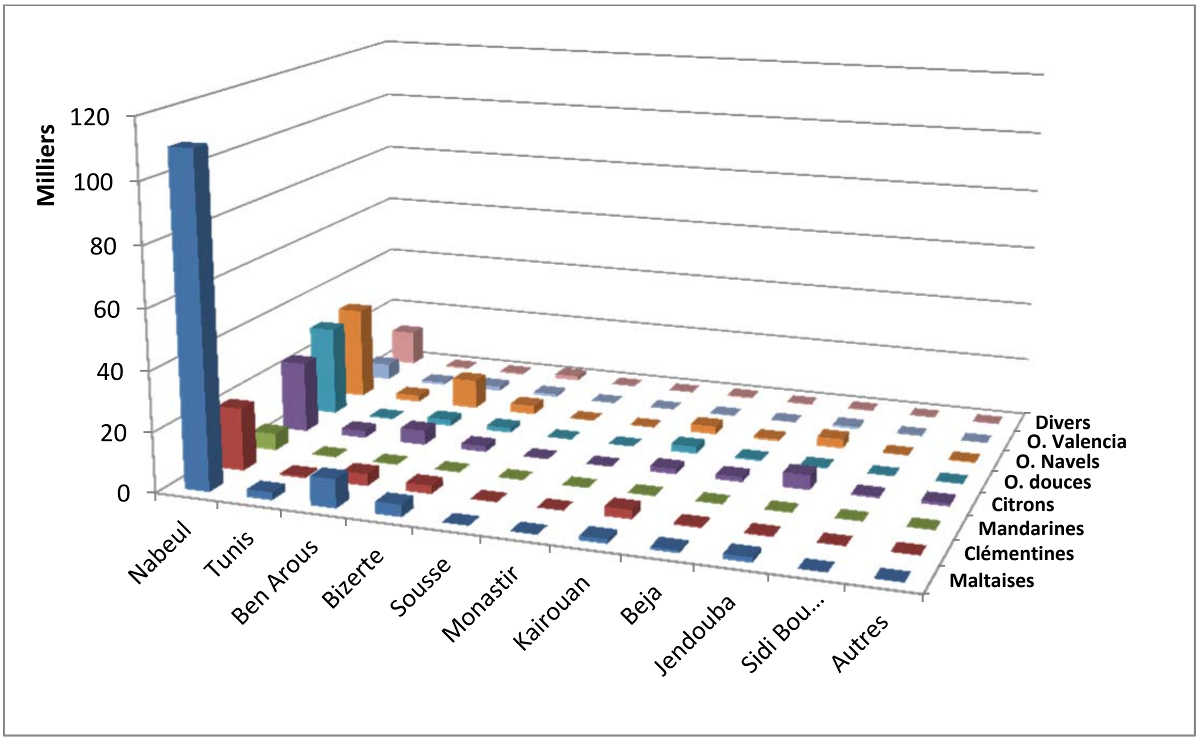
Source: CLAM data based on the European Commission AGRI.C.2 / AGR26 / 2012

Figure 3 - Evolution of citrus fruit production in Tunisia (thousands of tonnes)



Source: DGPA/GIFruits – final pre-estimation, crop year 2012/2013

Figure 4 - Production by governorate (tonnes)



Source: DGPA/GIFruits updated on 5 February 2013

Figure 5 - Citrus fruit production in Tunisia by variety (thousands of tonnes)

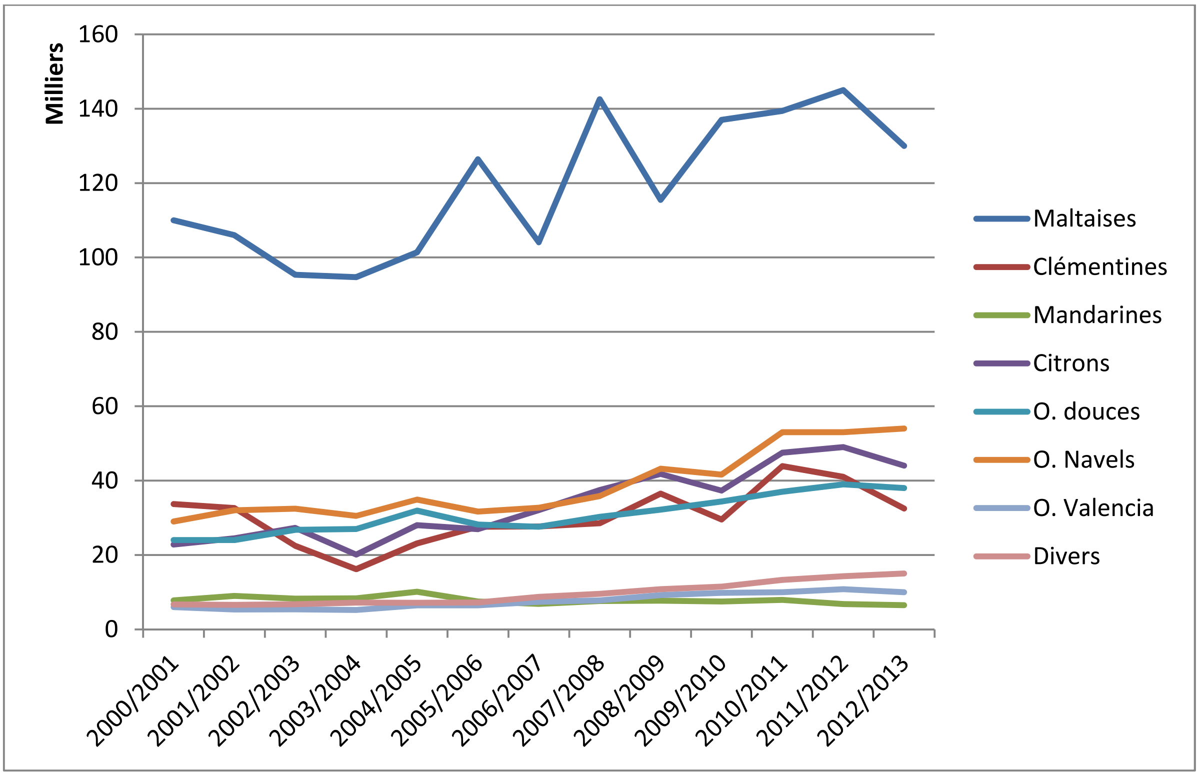
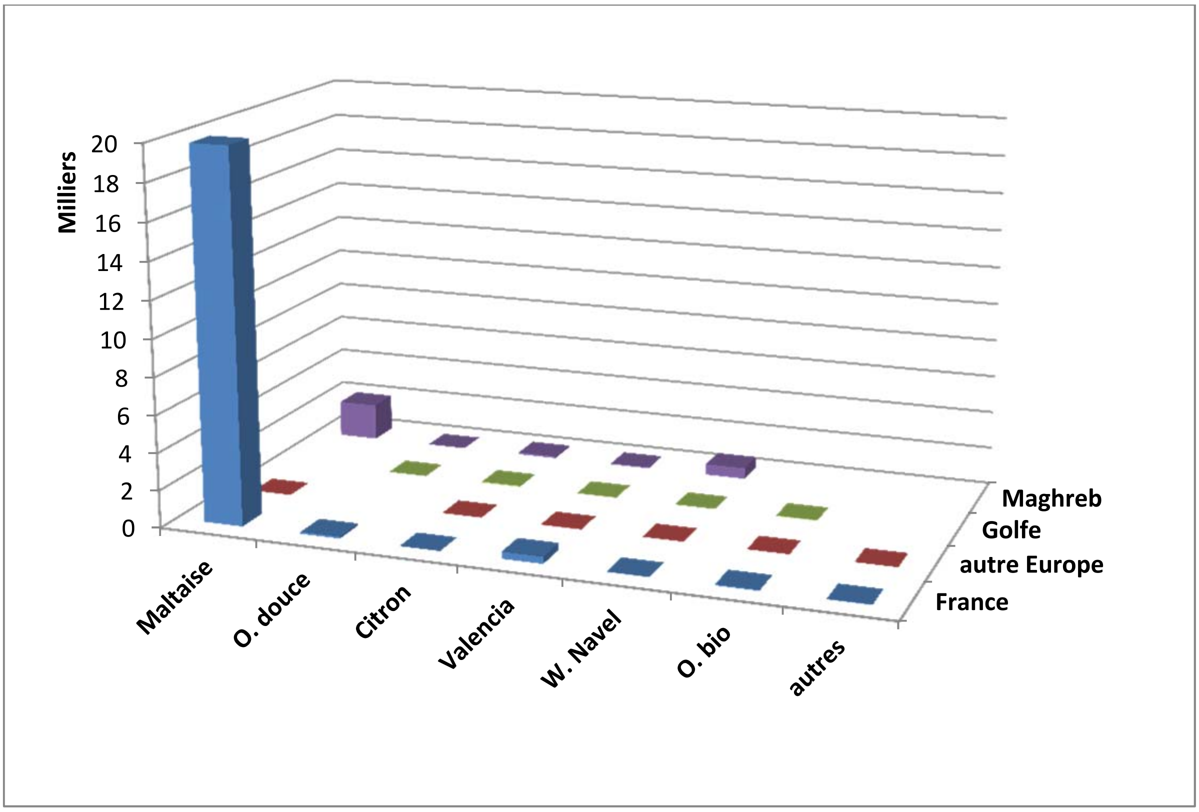


Figure 6 – Exports of Tunisian citrus fruits (2011-2012)



Source: GIFruits, inter-professional fruit group

4. Research: innovation, technical controversy and technological orientation

Following the interviews with the operators in the Tunisian citrus fruit value chain, we identified certain scientific and technical questions subject to controversy and associated with major economic objectives. To achieve this, we combined an analysis of the literature in the scientific and extension reviews such as Fruitrop, the reports of the Euromedcitrusnet project, the conferences of the IOCV and a selection of technical manuals to understand and summarise these objectives.

In Tunisia, certain research actions in the field of citrus fruit farming covered the following themes: clonal selection of some varieties of citrus fruit farmed in Tunisia; viral sanitation and the improvement of citrus fruit varieties and rootstock, the study of phytophagous citrus fruit mites and the introduction of methodologies to combat them, citrus fruit mal secco with its diagnosis, chemical measures and varietal resistance and finally the study of stubborn and tristeza, diseases found in citrus fruits, and their vectors.

In light of the objectives and the focus of the Sustainmed study on international competitiveness for the citrus fruit value chain, we chose to explore two essential subjects in detail: the question of the rootstock and the tristeza virus on the one hand and the conditions of implementing measures to combat diseases and parasites on the other.

4.1 Rootstock: the bitter orange or not?

Very often, in the fields of perennial plants and tree crops, technological progress is achieved through the improvement of plant material, rootstock or variety depending on the case, with clearly defined selection criteria: plant productivity, fruit quality, production period, adaptation to the edaphic conditions, temperature and soil and, increasingly, resistance to disease.

In the case of citrus fruits, a technical controversy has arisen concerning the oldest and most widespread rootstock in Tunisia – the bitter orange[10]. The bitter orange is a rootstock which is sensitive to the viral disease "*Tristeza*". The biological solution to combat this viral infection involves substituting the rootstock for more resistant varieties.

4.1.1 The economic importance of the illness

The importance of this disease makes it the source of a major economic and technological risk. The Citrus Tristeza Virus (CTV) is the causal agent of the most economically important disease

[10] The bitter orange originally comes from south-east India. It was brought to the Middle East by the Arabs before being introduced in Europe during the Crusades in the 11th century.

affecting citrus fruits worldwide. During the last century, the disease destroyed almost 70 million citrus fruit trees grafted on bitter orange trees around the world. In Spain alone, 40 million trees were destroyed (Marroquin et al., 2004). The range of tristeza virus hosts is essentially restricted to the genus Citrus spp. The Citrus Tristeza Virus (CTV) is transmitted by grafting and by several species of aphid, the most prolific of which is the brown citrus aphid (Toxoptera citricida). The second half of last century was marked by a considerable extension of this potential vector.

The following prevention strategies can be adopted: (1) consolidation of quarantine measures and vigilance at border posts; (2) controls in nurseries producing seedlings; (3) sensitisation of producers to the significance of tristeza; (4) production of certified seedlings; (5) monitoring of the dynamics of the aphid populations responsible for transmitting CTV; and (6) substitution of the bitter orange with another rootstock which is more resilient (ONSSA, sd).

The symptoms caused by CTV differ according to the isolates and species of the host plants. Seedlings grafted on bitter orange trees wither and the size of the fruit is reduced. The trees turn a bronze colour before losing their leaves then die following the destruction of the conductive tissue for nutrients or sap at the grafting points (ONSSA). In some cases, the primary and secondary veins become lighter while depressions form on the trunk of the plant taking the form of longitudinal grooves, hence the term “stem pitting”.

According to Roistacher and Moreno (1989), the destruction of millions of trees by tristeza between 1930 and 1950 was even one of the main reasons underlying the creation of the IOCV [11] in 1957.

[11] IOCV: International Organization of Citrus Virologists

“Historically speaking, when *Toxopteracitricida* is introduced into a country, citrus fruits grafted on the bitter orange leave the country for good” (Roistacher & al., 2010) p. 1. Numerous indexing and eradication programmes were introduced between 1970 and 1980 accompanied by numerous grubbing-up operations in Argentina, California, Spain and Israel. These programmes, supported by the development of ELISA indexing techniques, did not all achieve their objectives. Every attempt to save the bitter orange as a rootstock by means of cross protection failed[12] (Roistacher & al., 2010) p.1.

4.1.2 The advantages of the status quo

In light of this objective, all the citrus fruit producers around the world, and in particular in Tunisia, should renew their orchards. However, Tunisia has as yet remained unscathed by this virus. The rootstock is one of the essential factors of success of production due to the resistance it confers with regard to biotic constraints (destructive diseases and pests as well as degenerative and abiotic diseases (soil acidity or alkalinity, salinity, reaction to cold or drought) (CTA, 2010). The rootstock has a strong impact on factors such as robustness and the first production age, the output and quality of the fruit. Use of the bitter orange presents numerous advantages of which producers are aware.

The quality of the citrus fruits adapts well with the bitter orange – in particular the variety “Maltese half blood” for which we have already seen the importance and particularity of the market – and demonstrates a better adaptation and a better quality than with other rootstocks while also adapting better to both climatic and edaphic condition, and this for all types of varieties. This is also the case with new varieties such as “*New hall*”, “*Washington Navel*” and “*Navelate*”.

Although the other rootstocks adopted in Spain and imported to Tunisia boast the advantage of resisting the *tristeza* virus, the price of these rootstocks is very high and does not, therefore, encourage small-scale farmers to adopt them. Citrus fruit farmers are familiar with the bitter orange and demonstrate good mastery of the grafting technique.

We must also cite the importance of the link between the rootstock and the demands of the market. On the fresh fruit market, the quality of the “*Maltese half blood*” makes the difference and it is its organoleptic characteristics which enable it to compete with the oranges of the other countries of the Mediterranean (cf. supra). The definition of organoleptic quality varies between the different countries in line with the ease of peeling, the colouring and the thickness of the bark.

[12] Cross protection consists of infecting the rootstock with mild strains of the virus: it is a kind of pre-immunisation

All of these elements contribute to defining the quality of the fruit. As a rootstock, the bitter orange preserves the quality of this product. Finally, despite its sensitivity to the *tristeza* virus, this product remains the most frequently adopted by farmers.

The “*Poncirus*”, “*Citrange*” *and* “*Citrumelo*” are now available as replacements for the bitter orange with its sensitivity to “*Tristeza*”. New rootstocks are created by hybridisation or through biotechnologies, including “*Citrange Carrizo*”, “*Citrumelo 4475*”, “*Citrange C-35*” and “*C. volkamérina*”. These varieties are more resistant to the “*tristeza*” virus and better adapted to the new densities and production techniques (CTA interviews, 2011), although their adoption by farmers remains critical.

In conclusion, we identified the adoption of new rootstocks as an indicator of attention to innovation, although we are fully aware that this adoption can be viewed differently by the producers who evaluate the advantages and risks in light of the costs of change.

4.2 From chemical measures to integrated mechanisms

As in most producer countries, Tunisian citrus fruit farming has followed an evolution of techniques for combating pests aimed at reducing the quantity of pesticides used reflecting developments in society including environmental protection, a reduction in residues, the development of import standards, specifications (Globalgap), resistance to treatment and the destruction of useful insects (bees).

It is recognised that shifting from a treatment schedule to an integrated mechanism requires very good familiarity with the biology of the plant and its parasites, a much higher level of technicality, a significant technical supervision and the mobilisation of major collective and public resources.

As for all crops, the number of parasites and potential diseases is very high. The “EuroMedCitrusNet”[13] programme presents ten sorts of virus or viroids, one bacterium and one phytoplasm, five types of fungus, four types of nematodes, nine species of spider, seven species of insect and eight species of cochineal. Of course not all of these species have the same economic importance either in terms of the damage caused, spatial dissemination or the difficulty experienced in eradicating them or limiting their extension.

4.2.1 The example of the Mediterranean fruit fly

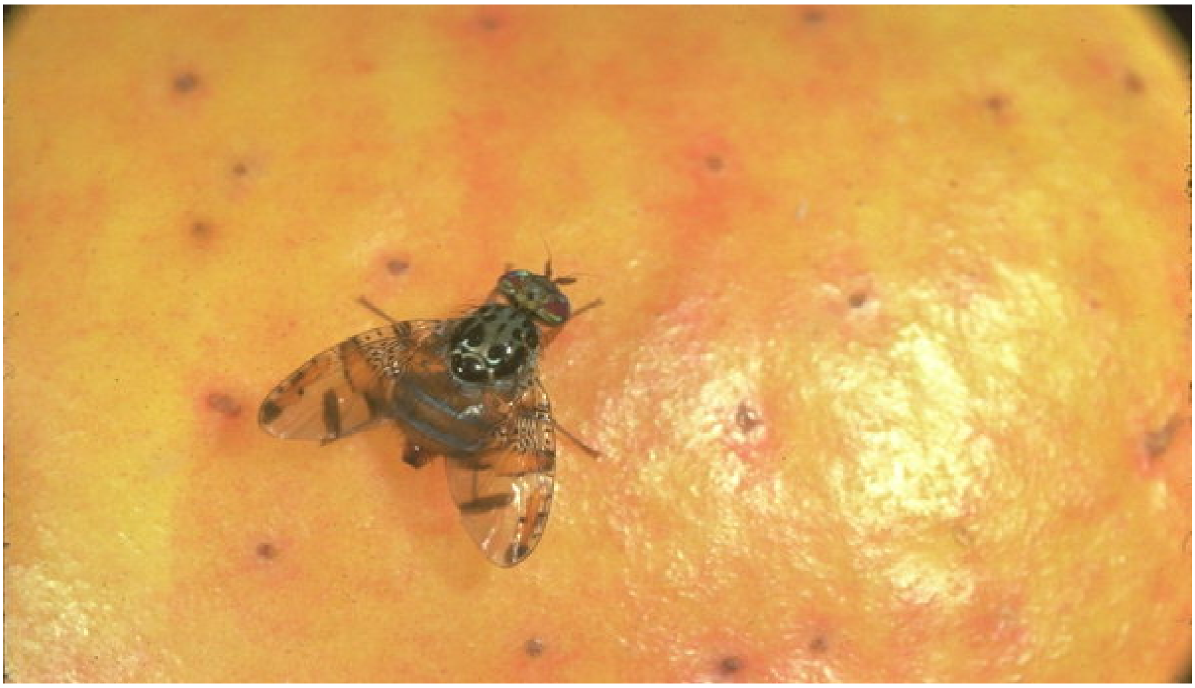
In the Mediterranean region, Ceratitis capitata – or the Mediterranean fruit fly – is the most formidable pest as a result of the favourable conditions observed in a large part of this area, in

[13]http://www2.spi.pt/euromedcitrusnet/

particular the climate and diversity of crops. Being very polyphagous with a high level of ecological tolerance also enables it to express its biotic potential to the full and to make optimum use of its environment by developing several generations every year and attacking numerous species of fruit tree demonstrating year-round production (Mazih, 1992).

The fly lays between 300 and 1,000 eggs throughout its life and the larvae create galleries through which the fungi and bacteria responsible for decomposition and premature falling of the fruit can enter. This damage represents a major obstacle to exports due to the depreciation of the value of the goods and the quarantine measures imposed by certain importing countries. On citrus fruits, the Mediterranean fruit fly targets early varieties and varieties with a thin skin, in particular the clementine. The high risk period is at the start of autumn and the end of spring.[14]

Figure 7 – Ceratitis capitata (Wiedemann) (Coutin R. / OPIE) Adult female preparing to lay her eggs in a peach. Source HYPP Zoologie



Over the past two decades, Malathion[15] - a non-selective insecticide applied from September until the end of November, a period when the fruit fly causes maximum damage and multiplies the most – was the weapon of choice in the fight against this fly. This product is now prohibited in Europe. Furthermore, the Mediterranean fruit fly has developed resistances through mutation. The chemical measures proved insufficient to control this pest. Despite the treatments carried out, losses due to the Mediterranean fruit fly in Tunisia are roughly USD 10,500,000 per year (Driouchi

[14] Source : http://bacteries-champignons.blogspot.fr/2012/02/methodes-de-lutte-contre-la-ceratite.html

[15] For the European union: this active ingredient is prohibited by decision 2007/389/EC following the examination of the inscription in appendix I of directive 91/414/EEC and since 2012, the residue rate for this pesticide in food is regulated in Europe

A., 1990, quoted by Lachiheb Abdallah, 2008). Nor should we forget the impact of these treatments on the environment, human health and useful auxiliary entomofauna (Lachiheb Abdallah, 2008). Despite the numerous works carried out on the different parasites, the results are relatively weak due to the difficulties of breeding and the complexity of the host-parasite (Lachiheb Abdallah, 2008).

In looking for substitution solutions, the CTA experimented with the technique of releasing sterile males from 2005-2006[16] (Lachiheb Abdallah, 2008). This technique was implemented in 2003 with a partnership between the Ministry of Agriculture and the National Centre for Nuclear Sciences and Technologies (CNSTN) in Sidi Thabet where the insects were bred and sterilised. This project received funding from the FAO and the CNSTN.

To eradicate this fruit fly, a large number of sterile males must be released for the approach to be successful. However, the number produced in Sidi Thabet was limited to between 8 and 10 million pupae or chrysalis per week to cover all the citrus fruit farming areas. The personnel and logistical resources were also limited. The experts therefore chose a zone measuring 5,000 hectares, isolated and bounded by the sea around Hammamet. The sterile insects were released three times a week on plots each measuring one square kilometre at 196 points identified by GPS, with a double dose around the edge to avoid contamination. The sex-ratio, weight and quality of the insets released were monitored.

The project lasted two years but did not achieve its objectives. Hammamet is a tourist area, the farmers were absent from their farms and were neither attentive to nor made aware of the presence of the fly. The relay funding of DTN 500,000[17] was not obtained. It also proved difficult to optimise the breeding process and only 2 million pupae or chrysalis, were produced instead of the expected 10 million.

The project of releasing sterile males was thus replaced by the installation of a network of traps to monitor the fruit fly population, thereby facilitating the reasoned application of chemical treatment by the farmer. From an integrated approached, we had returned to the reasoned approach.

We observe here a limit to technological development. The action undertaken requires public investment and collective action which is difficult to implement. A “diffusionist” vision of technical progress is not relevant in this case as an action must be introduced with sufficient resources. If the critical mass is not achieved, the technology cannot be disseminated.

[16]For a detailed presentation of the technique, see Lachiheb Abdallah, 2008

[17]About € 250,000

4.2.2 Pursuing biological control actions

The CTA has nevertheless not given up and, as part of a new strategy of the Ministry of Agriculture and the Environment, it is pursuing the development of biological control by creating an insectarium with a view to producing auxiliaries which attack the main parasites. The insectarium of the Citrus Fruit Technical Centre Technique has launched the following biological control programmes:

- biological control of *Planococcuscitri* with the predator *Cryptolaemusmontrouzieri* and the parasitoid *Leptomastixdactylopii,*
- biological control of citrus leaf miner[18] *Phyllocnistiscitrella*: the exotic ectoparasitoid *Citrostichusphyllocnistoides*.
- biological control of *Iceryapurchasi* by means of the predator *Rodoliacardinalis*

The CTA is developing its breeding farms and increasing the number of biological enemies from 30,000 to 50,000 (see appendix 1). The limitations of these actions can be seen in the technical optimisation of production, the means of disseminating these auxiliaries and thus the size of the zones protected. The resources allocated to developing this type of collective action should probably be increased.

Similarly, the CTA calls on its employees to implement a mass trapping approach by distributing 40 to 50 traps per hectare to the tree farmers at a subsidised price. These traps are sold by specialist manufacturers who combine an attractive substance (DAP[19]) with an insecticide. The product can be purchased directly by the citrus fruit farmers, although the price remains high at about TND 600 (€ 300).

The integrated approach remains the *de facto* reference: it is encouraged by research institutions and large farms such as the SMVDA[20]. This practice is based on eliminating weeds, introducing balanced fertiliser, watering the citrus-fruit seedlings regularly, annual pruning to aerate the plants, burying infected plans and the rest of the harvest deeper than 50 cm and complying with the harvest times before the risk of infection by the pests (AVFA, 2010).

[18] The citrus leaf miner or "Phyllocnistis citrella" was identified in Tunisia in 1994 having already been detected in other countries within the Mediterranean basin. This pest causes leaves to dry out and makes the citrus plant weak. Its presence can be identified by the symptom of the leaves rolling up (AVFA., 2010).

[19] DAP Di Ammonium Phosphate

[20] SMVDA: agricultural enhancement and development companies

4.3 Improving production techniques

Naturally, in the field of citrus farming and in Tunisia, we observe the improvement of a set of production techniques, which are significant when combined but which are no longer subject to any real controversy or difficulty at the research stage. We have nevertheless made an inventory of these improvements to demonstrate the innovative attitude of the farmers studied.

Irrigation: in dry areas, irrigation is essential. It can be practised by sprinkling under foliage or in a localised manner (diffuser, drip system). In this case, fertilisation can be combined with irrigation (ferti-irrigation) to save on inputs and ensure a regular supply of minerals (Alay P, Bazile D, De Bélizal E et al., 2009). This practice can be seen as modern and efficient. Similarly, it is possible to observe the existence of automatic or computer-operated irrigation. This practice is costly but has been adopted by certain SMVDAs and farmers with the necessary resources (source: our survey).

Fertilisation: mineral fertilisation must offset exports of mineral elements by the fruit and prunings and ensure the growth of vegetative organs. Fertilisation can be based on the results of mineral analyses of the leaves and soil. (Alary P., Bazile D., De Bélizal E. et al., 2009). This practice is an indicator of innovative practices. In the survey, we observed that certain SMVDAs have these analyses conducted in Spain.

Water and soil analysis: before and after installing a fruit plantation, it is essential to know the physical and chemical characteristics of the soil. Similarly, controlling water quality is also an important practice. While nothing new, these techniques are indicative of a farmer's genuine understanding of technical matters.

4.4 Conclusion

With regard to the technological dynamics in the citrus fruit value chain in Tunisia, we retain two main questions which marks its competitiveness: the risk linked to the potential arrival of the tristeza virus and the massive destruction of orchards. The solution of using resistant rootstocks exists. Specific actions coordinated by the CTA are implemented to counter this risk. Nevertheless, major risk management is always faced with the same problem: as long as the producers are not directly concerned, as long as they do not see the consequences of this potential biological crisis[21], they are not ready to sacrifice their "acquired advantages".

The question of biological control is of a different type. Protection by pesticides is not really called into question. However, the attitudes of society in this respect change very rapidly. We

[21] France in the 19th century and California in the 1990s were faced with a major Phylloxera crisis which demonstrated the economic importance of such diseases and epidemics

simply have to look at the Ecophyto plan 2018[22], which recommends reducing the use of pesticides in France by 50%, to understand one of the main market orientations. The difficulty encountered concerns resources and collective action. The solutions are accessible.

5. *Typology of citrus farmers with regard to innovation*

5.1 *Introduction*

In order to understand the attitude of citrus farmers with regard to innovation and to measure the extent to which the main technologies available have been adopted, we conducted a survey of 161 citrus farmers. The variables identified relate to four categories: the characteristics of the farmer, the structure of the farm and its resources, technological innovations and finally the marketing conditions[23].

Nevertheless, the information concerning the frequency of adoption of innovative techniques, structural variables, various cross-referencing operations and correlation tests did not give rise to highly significant results[24]. The mass of data may have hidden the most essential points. For example, the usual links between the level of study and innovation, the size of the firm and innovation are not clearly identified. The "weight" of Cap Bon also limited the results.

We therefore decided to focus on a more synthetic approach aimed at differentiating citrus farmers with regard to their behaviour towards innovation by characterising their similarities and differences, thereby defining a typology.

Analysing the data by ascending hierarchical classification enable used us to identify four groups of producers who differ according to socio-professional criteria, the structure of their farm and their attitude towards technological innovation.

5.2 *Methodology*

Statistically speaking, the typology, aims to "*reduce the number of observations by grouping them into homogenous and differentiated classes*" (Evrard et *al*., 1993). Within an ascending hierarchical classification, Ward's method identifies the most distinct groups which maximise inter-

[22] Ecophyto 2018: in the wake of the Grenelle Environment Forum, the Ecophyto plan represents the commitment of the stakeholders – who together drafted the plan – to reduce the use of pesticides at national level. In particular, the Ecophyto plan aims to reduce the dependence of farms on phyto products while maintaining a high level of agricultural production in terms of both quantity and quality

[23] For more details see appendix 2

[24] The detailed presentation of the descriptive statistics of this survey is beyond the framework of this report. All the data were published in the research paper drafted by Leila Khefifi. (Khefifi L., 2012).

group variance. The classification adopted using this method leads to the broadest possible grouping of classes whereas more refined classes might exist. To identify the elements framing this typology, it is possible to conduct a discriminant analysis.

The discriminant analysis helps determine the variables which best explain membership of a group (Evrard et *al.*,*ib*.). The aim of this analysis is thus to identify the discriminant focuses, i.e. the variables which contribute most to characterising the types of producer (the variable to be explained). The explanatory variables are metric or, failing this, binary. The discriminant focuses represent the linear combinations of the explanatory *p* variables adopted. Three farmers were eliminated from the analysis as a result of missing data and 158 citrus farmers were therefore retained for the analysis.

Wilks' lambda test enables us to validate statistically the explanatory weight of discriminants functions or focuses 1 to 3: 46.2% of variance for focus 1, 32.1% for focus 2 and 21.7% for focus 3.

The following graphic offers an initial visualisation of the 4 groups of farmer identified by the hierarchical classification. The coefficients from the matrix of the structures enable us to identify the variables "weighing" on these two focuses:

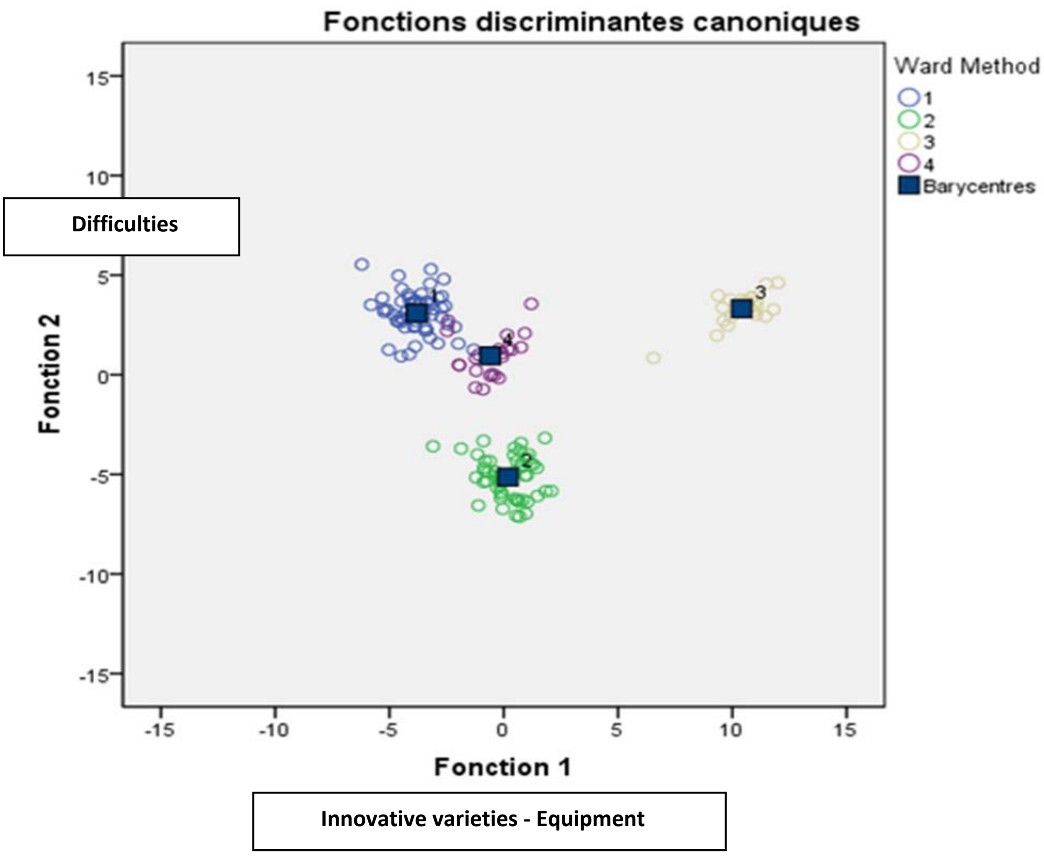
The structure matrix only includes a selection of the variables contributing the most to the two discriminant focuses. The measuring scale runs from -1 to +1. Focus **1** describes the innovative varieties and technical equipment (tractor, sprayers, etc.). Focus **2** describes the variables of difficulty (water salinity, soil type, sale of production, diseases (mal secco), lack of monitoring, input supplies). Focus **3** describes the indicators of technicality: agricultural training, membership of a cooperative, innovative pruning techniques and the qualifications of temporary workers and permanent staff.

Table 1 - Summary of the canonical discriminant factors: own values

Function	Own value	% variance	% aggregate	Canonical correlation
1	21.115[a]	46.2	46.2	0.977
2	14.636[a]	32.1	78.3	0.967
3	9.910[a]	21.7	100.0	0.953

Once these analyses have been conducted (hierarchical classification then discriminating analysis), we must undertake a descriptive analysis of the four producer profiles. All the figures presented satisfy the criterion of statistical validity (Chi-Deux test for qualitative data and ANOVA for averages).

Figure 8 – Map of the regions of use



The coefficients from the structure matrix enable us to identify the variables "weighing" on the two focuses:

Function 1 consists of the innovative varieties with positive scores (0.1 "*Navellate"*» + 0.099 "*cassar*" + 0.095 "*Thompson navel*" and innovative production techniques such as the use of technical extension equipment (tanks (0.082), sprays (0.091), innovative pruning technique (0.079), soil analysis (0.097), incentives such as subsidies[25] (0.073), the technique of pollination (0.059), automatic irrigation (0.040) and investing in new production techniques (0.028).

We should underline the fact that the function does not only represent the new varieties as the "Maltese half blood" variety – which is a local variety – is also included in function 1 with a positive score (0.070).

[25] Subsidies concern inputs treatment products and fertiliser for small-scale producers, hedgerows, the drip system, mass traps and the adoption of new varieties such as the Maltese balerin.

Function 2 consists of the problems which result in a difficulty in adopting technical innovations in the citrus fruit sector, including soil salinity (0.072), soil type (0.70), problems relating to the sale of production (0.066), the lack of technical monitoring (-0.054), problems relating to the supply of inputs (0.046) and diseases including mal secco (0.061).

Table 2 - Functions at the barycentres of the groups; Ward's method

Group	Function 1	Function 2	Function 3
1	-3.814	3.095	-1.701
2	0.180	-5.139	-0.841
3	10.409	3.316	-1.190
4	-0.594	0.953	7.478

Function 3 consists of organisational innovation and the technical competencies of the farmers surveyed, including agricultural training (0.71), membership of a producers' association or a cooperative, specialisation in the technique of irrigation (-0.63), technical experience (-0.040) and familiarity with the extension techniques in citrus fruit technical centres (-0.28).

5.3 Results

The summary figure table below (figure 6), based on the two main discriminant focuses, shows groups 1 and 4 to be quite close while the other two groups are better discriminated. The characterisation of the groups of producers is explained, completed and refined by "calculating" the values of each variable for each type of tree farmer, "reconstructed" in this way. It is these data which are specified for the refined description of each category.

Table 3 - Farmers investing in new production techniques

	NO	NO %	YES	YES%	
Group 1	38	64%	21	36%	59
Group 2	30	56%	24	44%	54
Group 3	10	45%	12	55%	22
Group 4	16	70%	7	30%	23

5.3.1 Group 1

Group 1 can be defined as "elderly, small-scale producers with little training, little innovation and in search of support".

They are elderly people farming small areas (four-fifths have less than 5 ha) whose education stops at secondary level. One-third of them have followed a specific training in new production techniques like groups 2 and 4, which is low compared to the 61% of group 3. One-quarter of them are members of a collective organisation.

They invest little in new techniques[26], with one-third of the group (36%) investing, only slightly more than group 4 (30%) and well below the levels observed in groups 2 and 3. Proportionally speaking, they make much greater reasoned use of inputs. Three-quarters of them have higher-density plantations (6x4, 6x3) and they adopt an integrated control approach while making little use of soil analysis and subsidies.

They plant new varieties, but in small quantities, given that they farm small areas. It is the group which most frequently believes it is lacking information and supervision but, somewhat astonishingly, suffers the least from disease. It records the lowest outputs, always lower than 20 t/ha. These tree farmers are primarily located in the governorates of Nabeul and Kairouan.

5.3.1 Group 2

Group 2 can be defined as "Elderly small-scale producers who are nevertheless trained, relatively innovative, subsidised and in technical difficulty"

As with group 1, this group consists of older individuals (only slightly more than group 1) farming small areas (four-fifths of them have less than 5 ha). Their level of education is higher with 37% having a university education. The level of education would not therefore be a factor limiting innovation. One-third of them have followed a specific training in new production techniques, like groups 1 and 3.

One-quarter of them are members of a collective organisation (average data as in group 1). Almost half of the group invests quite considerably in new techniques, only slightly less than group 3 (55 %). This is the group in which the highest proportion of orchards demonstrating the traditional density (6x6), which makes the least reasoned use of inputs (as group 3) but which nevertheless adopts an integrated approach (like group 1) and the practice of soil analysis.

[26] Methodological note: the results of the answers to the general question "Do you invest in new techniques?" may contradict the answers to more specific questions such as those concerning soil analysis, integrated control, biological control or new densities. This question nevertheless summarises the opinion of the people surveyed.

Table 4 - Structure matrix

	Fonction				Fonction				Fonction		
	1	2	3		1	2	3		1	2	3
Navel-Late	,100*	0,059	-0,03	SAKASTLI	,048*	0,034	-0,024	Pulvérisateur	,066*	0,03	0,006
Cassar	,099*	0,038	-0,013	MALATAISE DOUCE	,048*	0,018	0,017	Charrue	,062*	0,013	-0,006
Thompson navel	,095*	0,055	-0,033	Caffin	,047*	0,034	-0,02	Pollinisation	,059*	0,027	-0,014
Maltaise Blonde	,088*	0,03	0,013	Valencia Late	,045*	-0,022	0,005	Ouvrier permanant qualifié-irrigation	,043*	-0,007	0,001
Eureka	,078*	0,044	-0,009	Marissol	,045*	-0,002	-0,026	Innov- irrig.-automatique	,040*	-0,001	-0,034
Double fine améliorée	,077*	0,059	-0,032	analyse du sol	,097*	-0,049	0,034	Identif besoin irrig.	,036*	-0,013	-0,001
MA3	,076*	0,057	-0,053	atomiseurs	,091*	0,034	0,054	Arrachage	,028*	-0,009	0,018
Tarocco	,073*	0,034	-0,018	citernes	,082*	0,031	-0,04	Investir nouvelles techniques	,028*	-0,011	-0,024
Maltaise demi sanguine	,070*	-0,016	-0,043	Innov. taille	,079*	-0,017	0,032	Calendrier de travail	,024*	0,016	-0,023
				Subvention	,073*	-0,038	-0,032	Porte greffe bigaradier	,019*	0,002	0,005
				tracteur	,069*	-0,004	-0,034				
	Ft1	Ft2	Ft3		Ft1	Ft2	Ft3		Ft1	Ft2	Ft3
New-hall	,067*	0,061	-0,043	Formation agricole	-0,001	0,005	,071*	Source d'information	0,202	-,255*	0,058
Star-Ruby	,059*	0,027	-0,014	Appartient à une association de producteur/coopérative	-0,024	-0,001	,070*	Salinité	-0,011	,072*	0,022
Lana- Late	,059*	0,038	0,034	Taille	0,046	0,023	-,057*	Sol	-0,001	,070*	0,012
Hernandina	,059*	0,029	-0,018	Ouvrier qualifié pour l'irrigation	0,026	-0,054	-,063*	Problèmes au niveau de l'écoulement de la production	0,032	,066*	0,046
Faminello	,058*	0,036	-0,021	Nombre de jour occasionnel	0,003	-0,011	-,044*	Mal- Secco	-0,032	,061*	-0,02
Antracnique	,057*	0,026	-0,014	Salaires permanents	0,018	0,016	-,040*	Manque de suivi	-0,015	,054*	-0,019
Meski- Sifi	,053*	0,033	-0,023	Choix influencé	0,02	0,027	-,028*	Approvisionnement en intrants	-0,025	,046*	-0,006
Ballerin	,051*	0,034	0,036					Utilisation raisonnée des intrants	-0,029	,031*	0,004
Santa-Terresa	,048*	0,024	0,038								
« Mandarinier-commun »	,049*	0,017	-0,023								

Two-thirds of the members of this group have access to subsidies. They plant news varieties slightly more extensively than in group 1. The members of the group demonstrate the lowest tendency to believe they lack information and supervision but, somewhat surprisingly, suffer the most from disease. The farmers in the group demonstrate the lowest output, always lower than 20 t/ha, although they nevertheless use new varieties. They are primarily located in the north (Bizerte, Beja and Jendouba) with only one-third established in Nabeul, compared to two-thirds for the other groups.

5.3.2 Group 3

Group 3 can be defined as “Young small-scale producers who are trained, highly innovative and not experiencing technical problems”.

These are young individuals (32% are under the age of 44) faring small areas (four-fifths of them have less than 5 ha). They boast the highest level of education with 45% enjoying a university education. Two-thirds of them have followed a specific training in new production techniques, i.e. twice as many as the other groups. Very few farmers in this group (14 %) belong to a collective organisation, which is the lowest proportion.

This group invests most in new techniques, boasts the lowest proportion of orchards with a traditional density (6x6) has a large share (73%) of average densities (6x4), uses inputs in a reasoned manner (like group 2), makes little use of integrated control (like group 4), but relies heavily on soil analysis (77%). They plant a significant quantity of new varieties.

Less than one-quarter of this group believe they are lacking information, but two-fifths feel they need more supervision. It is also the group which experiences the most problems with disease. Group 3 records outputs which are slightly higher than groups 1 and 2. They use new varieties and are primarily located in the governorate of Nabeul (two-thirds).

5.3.3 Group 4

Group 4 can be defined as “Young large-scale producers who are highly trained, cooperative, the least innovative, productive and experiencing few technical problems”.

This group stands out with a considerable number of large-scale farms compared to the other groups. Only 17% of them farm less than 5 hectares while the other farmers are divided more or less evenly between the surface area categories of 5-10 ha, 10-50 ha, and more than 50 ha. Their level of education is high, with 61% having reached secondary level and 35% having enjoyed a university education. One-third of them have followed a specific training in new production techniques like those in groups 1 and 2.

In contrast to group 3, more than half of the members of this group (52 %) are members of a collective organisation, which is the highest proportion across all groups. It is the group which invests least in new techniques (30 %) and has the lowest proportion of orchards planted with the traditional density (6x6), although it has a large share (73%) of average density orchards (6x4). This group makes least use of reasoned inputs (like group 3), little use of the integrated approach (like group 4) but average use (48%) of soil analysis.

Only one-third of the members of this group have access to subsidies, as in group 1. They plant a large quantity of new varieties. One-third of this group believes it has insufficient information and supervision although the group is little affected by problems relating to disease (10%). Group 4 boasts the highest output with four-fifths of the producers enjoying an output greater than 20 t/ha. They are primarily located in the governorate of Nabeul (70%).

5.4 The questions which do not distinguish the groups

A number of questions provide statistical results which are very similar for all four groups: these are criteria relating to soil salinity, soil type, problems in selling production, diseases such as mal secco and the supply of inputs. This means that these questions or difficulties are perceived in a similar manner within each group.

5.5 Conclusions

The analysis by ascending hierarchical classification identified four groups enabling us to consider the adoption of technological innovations in the Tunisian citrus fruit value chain. The first observation is the absence of a strong polarisation of these groups for a limited number of criteria. Groups 1, 2 and 4 are relatively similar with regard to focus 1 while groups 1, 4 and 3 are relatively similar with regard to focus 2. This observation confirms the difficulty encountered previously to isolate simple and significant correlations.

We nevertheless discover the usual criteria of the relationship between technological innovation and the socio-professional and structural characteristics of tree farms exploitations, in particular the positive roles of education, the size of the farms and the existence of subsidies.

Group 3 nevertheless calls into question the hierarchy of these usual criteria. It is a group with a very high level of education and which is both highly innovative and highly individualistic but which is blocked by the control of very small areas.

Counter-intuitively for a developing country where the level of education of the farmers is often very low, we witness a contrasting situation here. It is the access to the land as a factor of production which becomes the most selective criterion, not the level of education. However, the traditional relationship between education and innovation works very well in this case.

The model of innovation dissemination through collective action and cooperation is overtaken by a more “individualistic” model of innovation in which young farmers with higher education seem to be spontaneously oriented towards technical progress.

6. General conclusion

We can begin by reiterating the main partial conclusions presented in the course of this work. First, Tunisia is an atypical operator on the international citrus fruit market as it is a small-scale operator with small-scale production, weak exports, a specialisation in one main variety and a focus on a specific market: France. With regard to the technological and research objectives, we have retained the major technological risk of tristeza virus, which is something of a sword of Damocles. The change in collective constraints for the adoption of new methods of combatting diseases and predators is also cited: significant collective means with a threshold effect are necessary to facilitate a greater effect of biological control compared to conventional chemical control methods.

Citrus fruit farmers adopt technical progress, albeit under original conditions. One of the groups demonstrates a very high level of education, is highly innovative, highly individualistic but appears to be blocked by the control of very small areas. The model of innovation dissemination through collective action and cooperation is superseded here by a more “individualistic” model of innovation in which young farmers with a higher level of education appear to be spontaneously oriented towards technical progress.

With regard to economic policy, the role of subsidies should be highlighted in adopting new techniques. Furthermore, the means required to fund the research and implementation of collective action aimed at providing phytosanitary protection would appear limited. Specific aid from the European or other donors could be justified, knowing that the social demand is increasing in this direction.

Two research approaches should complete these works. The first concerns the reciprocal influence of the domestic market and exports on the technological dynamics of the Tunisian citrus value chain. The relationships of product process and varieties, the growth of domestic demand, the arrival of new varieties on the domestic market and the increase in international competition on the citrus fruit market should encourage us to review the hierarchy of orientation criteria relating to technical progress. While it is important, the attention paid to the single niche market of the Maltese half blood must be complemented by incorporating other factors of diversification.

The second are for research should concern a sort of “benchmarking” of research into citrus fruit. The main rival countries would appear to enjoy resources and dynamics disproportionate to those observed in Tunisia. Instead of examining the different speeds at which technological innovations are adopted in the competitive advantage, this comparison should facilitate a better analysis of the different rhythms of the genesis of these innovations and the system (the innovation chains) which produces and guides them. It is in this way that R&D has become an essential factor in the competitive advantage of nations.

7. *Bibliography*

Alary P., Bazile D., De Bélizal E., Berland S., Besson I., Boulakia S., Bureau J.C., Caillavet F., Carraud M., Chapuis R., Charvet J.P., Cogny C., Delfosse C., Deprez C., Duquenoy A., Durbiano C., Estebanez J., Griffon M., et al., 2009, Nourrir les hommes : un dictionnaire, Neuilly : Atlande, Géographie thématique, 765 p.

AVFA Agence de vulgarisation et de formation agricole, Ben Abdelali Nasr et al., 2010, Guide de plantation des agrumes, Tunisie, 55 p. (en arabe), 2ème édition améliorée de 2003

Bergeret Pascal, Poppe Krijn J., 2012, Agricultural knowledge and innovation systems in transition, a reflection paper, Brussels, Standing Committee on Agricultural Research (SCAR), Collaborative Working Group on Agricultural Knowledge and Innovation Systems (CWG AKIS), March 2012, 121 p.

Commission Européenne, 2012, Groupe de travail Prévisions Agrumes, AGRI.C.2 / AGR26 / 2012 du 06/11/2012, 140 p.

CTA, Centre technique des agrumes, 2010-1, Lutte contre la Cératite Capitata, 12 p. http://www.cta.tn/documents/publication/ceratite.pdf

CTA, Centre technique des agrumes, 2010-2, Les porte-greffes des agrumes conseillés pour l'utilisation en Tunisie, 11 p. http://www.cta.tn/documents/publication/porte_greffes.pdf

Dosi G.,1988, Sources, procedures and microeconomics effects of innovations, Journal of Economic Literature, vol. 26, 1126-1171

Driouchi A., 1990, Evaluation économique des pertes causées par la mouche méditerranéenne des fruits: Cas de l'économie agricole Tunisienne Rapport de mission d'un expert consultant AIEA/FAO. Division de l'assistance technique et de la coopération, 22 p.

Evrard Y., Pras B., Roux E., (1993). *Market : études et recherches en marketing, fondements, méthodes*, Paris (FRA), Nathan, 1993, 629 p.

Gifruit http://www.gifruit.nat.tn

Khefifi Leila, ss la dir. de Montaigne E., 2011, L'innovation dans l'agrumiculture tunisienne, Montpellier, CIHEAM-IAMM : Master 2, Ingénierie des projets et des politiques publiques (I3P), Parcours IAMM « Développement Territorial et Projets », soutenu le 30-09-2011, 172 p.

Khimoud Djamal, Louni Ahmed, 2008, Estimation de l'infestation des différentes variétés d'agrumes par Ceratitis capitata Wied.,1824 (Diptera ; Trypetidae) en fonction de l'exposition dans différents vergers de la région de Tizi-Ouzou, Université Mouloud Mammeri de Tizi-Ouzou, Mémoire de fin d'études, Faculté des Sciences Biologiques et des Sciences Agronomiques, Département de Biologie en vue de l'obtention du Diplôme d'Ingénieur d'Etat en Biologie, Spécialité: Ecologie Animale, Option: Gestion des populations

Laajimi Abderraouf, Ben Mimoun Mehdi, 2007, Safe and High Quality Supply Chains and Networks for the Citrus Industry between Mediterranean Partner Countries and EuropeNational Citrus Sector Analysis: Tunisia. - Tunisia, Tunis, Institut National Agronomique de Tunisie, EuroMedCitrusNet Contract No. 43146 (Food Quality and Safety) November,Deliverable 9, 22 p.

Lachiheb Abdallah, 2008, Optimisation de la dose d'irradiation dans le cadre d'un projet de lutte contre la Ceratitis Capitata, Ecole supérieure d'agriculture de Mograne, Mémoire d'ingénieur 2008

Marroquin C., Olmos A., Gorris M.T., Bertoloni E., Martìnez M.C., Carbonell E.A., De Mendoza A.H. and Cambra M., 2004. Estimation of the number of aphids carrying Citrus tristeza virus that visit adult citrus trees. Virus Research **100**: 101-108.

Martin Ben R., 2012, The evolution of science policy and innovation studies, Research Policy 41 (2012) 1219– 1239

Mazih A., 1992. Recherches sur l'écologie de la mouche méditerranéenne du fruit *Ceratitis capitata* Wiedemann (Diptera, Tephritidae), dans l'arganeraie de la plaine du Souss (Maroc). Thesis Etat, Agadir.

Montaigne Etienne, 1992, Les techniques à membranes en oenologie : Une approche évolutionniste ? In : Innovation, changement technique et agro-alimentaire. - Paris : INRA, Economie et sociologie rurales : Actes et Communications n ° 8, 1992, p. 127-140

Montaigne Etienne, 1996, Théorie évolutionniste, dynamique technologique et systèmes d'approvisionnement alimentaires, Communication au séminaire sous-régional de la FAO (Dakar, 1997) : "Approvisionnement et distribution alimentaires des villes de l'Afrique francophone", 18 p. : FAO, "Aliments dans les villes" :
http://www.fao.org/waicent/faoinfo/agricult/sada/dada.htm

Montaigne Etienne, Coelho Alfredo, 2012, Structure of the producing side of the wine industry: Firm typologies, networks of firms and clusters. - Wine Economics and Policy 1 (2012) 41–53 - www.elsevier.com/locate/wep - Available online at www.sciencedirect.com

ONSSA sd, La tristeza est une maladie qui menace le patrimoine du Maroc, Royaume du Maroc, 4 p. http://www.onssa.gov.ma/onssa/fr/doc_pdf/Fiche_TK_Tristeza.pdf (2013-05-17)

Porter Michael, 1993, L'Avantage concurrentiel des nations, Paris, Dunod

Quelin Bertrand, Arregle Jean-Luc, 2000, Le management stratégique des compétences, Paris, Ellipses, 352 p.

Roistacher C. N. and Moreno P., 1989, TRISTEZA : The Worldwide Threat from Destructive Isolates of Citrus Tristeza Virus-A Review,Eleventh IOCV Conference 1989-11-06/1989-11-11, Orlando, p. 7-19

Roistacher C. N., Graça V. da and G. W. Müller, Cross Protection Against Citrus tristeza virus- a Review, Proceedings, 17thConference, 2010 – Citrus Tristeza Virus p. 1-27

Solow Robert M., 1956, A Contribution to the Theory of Economic Growth, The Quarterly Journal of Economics, Vol. 70, No. 1. (Feb., 1956), pp. 65-94

8. List of tables

9. List of figures

10. List of abbreviations

AKIS- *Agricultural knowledge and innovation systems*

AVFA - Agence de vulgarisation et de formation agricole

CLAM – Comité de liaison de l'agrumiculture méditerranéenne

CNSTN- Centre National des Sciences et Technologies nucléaires

CTA - Centre technique des agrumes

CTV - Citrus Tristeza Virus

DAP - Di Amonium Phosphate

DGPDA – Direction générale de la production et du développement agricole

DTN – Dinar tunisien

GIFRUIT – Groupement interprofessionnel des fruits

INAT - Institut National Agronomique de Tunis

INRAT - Institut National de la Recherche Agronomique de Tunisie

IOCV- International Organization of Citrus Virologists

SMVDA - Société de mise en valeur et de développement agricole

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12. Appendix 1 - Perspectives of CTA activity with regard to biological control

Subject of intervention	Indicators of good work progress	Date
Programme of biological fight against the citrus leaf miner, "Phyllocnistiscitrella"	-Breeding of imported parasitoids in the insectarium (2010). - About 30,000 biological enemies released in 50 locations in the governorates of Nabeul, ben Arous, Bizerte, Kairouan, Jendouba and Beja (2011) -About 50,000 biological enemies released in 70 locations in the different citrus farming governorates (2012) - Biological balance established between the pests and these predators	-2010 breeding imported parasitoids -2011 about 30,000 biological enemies released -2012 about 50,000 biological enemies released
Programme of biological fight against the citrus mealybug, "Planococcuscitri"	- Breeding of 500,000 predators and 300,000 parasitoids every year followed be release into affected fields located in Nabeul, Ben Arous, Bizerte, Kairouan, Jendouba and Beja to combat the citrus mealybug. - Biological balance established between the pests and these predators.	Breeding of 500,000 predators and 300,000 parasitoids every year
Programme of biological fight against the cottony cushion scale, "Iceryapurchasi"	- Breeding of predators and release of about 10,000 insects (2010) -About 40,000 predators released to combat the cottony cushion scale (2011). - About 50,000 predators released during the course of 2012. - Balance established between the pests and these predators.	-2010 Breeding of predators and release of about 10,000 insects -2011 About 40,000 predators released. - 2012 About 50,000 predators released.
Programme of biological fight against the leaf miner	Selection of the most effective parasitoids	-2009 prepare the project

		-2010 launch the project -2011 begin breeding predators -2012 begin releasing predators in the fields.
Pilot programme for the fight against the Mediterranean fruit fly in citrus orchards Introduction of new parameters concerning the mas trapping technique Use of new techniques to fight the Mediterranean fruit fly	Limit damage caused by the Mediterranean fruit fly, in particular in the biological system plantations.	-2010 complete the trapping study by DAP. -2012 close the studies concerning the introduction of new intensive trapping techniques. -2010-2011 introduce new parasitoids and determine their breeding conditions. -breed predators and begin to release them into the orchards.
Fight against the citrus leaf miner by mass trapping	Limit damage caused by the citrus leaf miner in particular in the biological system plantations	- 2011 determine the positions for the traps - 2012 determine the optimum plantation density

13. Appendix 2 – The questionnaire and the variables

The survey enabled us to define a set of variables based on the interviews and bibliographical research. These variables concern

- the profile of the farmer: age, level of education, non-agricultural activity, member of a farmers' association, specialised training or diploma for certain techniques or varieties, familiarity with the technique, interest in investing in new production techniques;

- the resources available at farm level: citrus farming area, water source, type of occupancy, type of soil, salinity, density, the varieties, i.e.: LaneLate, Sakastli, Nova, Maltese Balerin, Caffin, Valencia Late, Faminello, Tarocco, Double Fine Améliorée, New Hall, Naveliina, w Navel, Thomson Navel, Meski Arbi, Antracnique, Maltese half blood, Mandarinier Commun, Cassar, Moro, Encore, Chislet, MeskiSifi, Eurika, MeskiAnsli, Maltaise Douce, Maltaise Blonde, Starruby, Hernandina, MA3, Nuless, Interdonado, Marsh Seedless, Lunari, Marissol, Sainta Teresa and la Tanjarine, the water source, the information source, input supply, breeding activity: this variable is selected to see if there are any farmers interested in organic amendments such as manure in the context of reasoned agriculture, administration, pollination, work schedule, total production, labour, problem of water availability, problem of water tower, skilled worker, sanitation and drainage, reasoned use of inputs,

- technological innovations: irrigation innovation, identification of irrigation needs, integrated control, rootstock, soil analysis, subsidy, pruning innovation.

- the variables concerning commercialisation, problems in selling production, problems: input supply, financial, adaptation of new techniques, source of information, the impacted choice, insufficient information, insufficient supervision, increase in production, impacted choice, grubbing up, *mites, mal secco, gummosis, leaf miner, Mediterranean fruit fly, anthracnose.*

Given the limited time frame, we have attempted to answer the question by trying to choose the variables which have the greatest impact on the innovations, or in other words the variables which demonstrate a link with the innovative production techniques and which influence the dynamics of innovations such as pollination, soil analysis, input supply problems, the lack of supervision. Innovation can relate to resources, competencies or the profile of the farmer. It can also relate to the product or the organisation (Quélin B, Arrégle J l; 2000), hence the decision to identify and characterise the innovations according to the profile of the farmer and resources available on the farms.