Trade-offs analysis between Durum wheat yield and nitrogen efficiency in the fields of farmers in Tunisia

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Introduction

Satisfying the growing demand for agricultural products while improving N input efficiency in Mediterranean cereal systems (Hochman et al., 2013) will require significant change in cropping systems structure and management. Our hypothesis, developed from the concepts of eco-efficiency (Keating et al., 2010) is that it is possible to obtain a better compromise between production and resource efficiency by adopting transformational technologies, such as changing genotype or by temporal and/or spatial diversification of crops. In this study, the hypothesis is tested on rotation as a temporal complexification of a cereal system structure. We addressed the following question: does crop rotation allow for a better trade-off between nitrogen efficiency and yield of Durum wheat in farmers conditions and how far can it compensate for the reduction of area allocated to wheat?

Materials and Methods

We introduced in the efficiency analysis two intermediate variables between nitrogen supply and grain yield in order to establish a four-quadrant diagram (Fig 1). Nitrogen uptake was used, on the right of this diagram, to separate the efficiencies of resource capture and resource conversion (De Wit, 1992). On the left, N-efficiency was introduced as intermediate variable, in order to visualize trade-offs between efficiencies and production or input. In each quadrant we established boundary curves which represent the maximum achievable performances (yield, N uptake, N efficiency) when the input (here N fertilizer) is the only limiting factor. This framework has been tested on 432 “agronomic situations” (climatic year, previous crop and N rate) of Durum wheat in farmers' fields representative of the diversity of farmers practices in four regions of Tunisia.

Results and Discussion

Nitrogen capture by Durum wheat is benchmarked against boundary curves that represent achievable nitrogen uptake when nitrogen supply is the only limiting factor (Fig 1.A).These boundary curves were significantly different according to the preceding crop. The highest achievable N absorbed was found for irrigated wheat grown after vegetables (CM_Dwi), followed by rainfed wheat grown after legumes (LG_Dwr). In contrast, the lowest achievable N absorbed was found for rainfed wheat in a cereal-wheat rotation (CE_Dwr), revealing the poor N-capture potential of rotation sequences based on cereals only. Our method of estimation of N absorbed (Fig 1.B) does not allow discussion of the effect of the preceding crop on the efficiency of N conversion into grain but experimental data showed that this factor does not break the proportionality of yield to N absorbed. The equations of boundary curves of quadrants A and B allowed us to establish the trade-off curves between N efficiency and an objective of grain

production (Fig 1.C) or of N fertilizer use (Fig 1.D). They show that in cereal-based systems of Tunisia high N efficiency can be obtained but only with low level of fertilization and grain yield. Changing the preceding crop into legume does not change this tendency but creates a new efficiency frontier which allows both an increase in Yield and N efficiency (Fig 1.C), especially if the level of N fertilizer used on this area has to be limited for environmental purposes (Fig 1.D). In irrigated systems, where wheat is grown after vegetable, these shifts in the efficiency frontiers are sufficiently high to compensate for the reduction of Durum wheat area in a 3 years rotation, especially at low level of N fertilization.

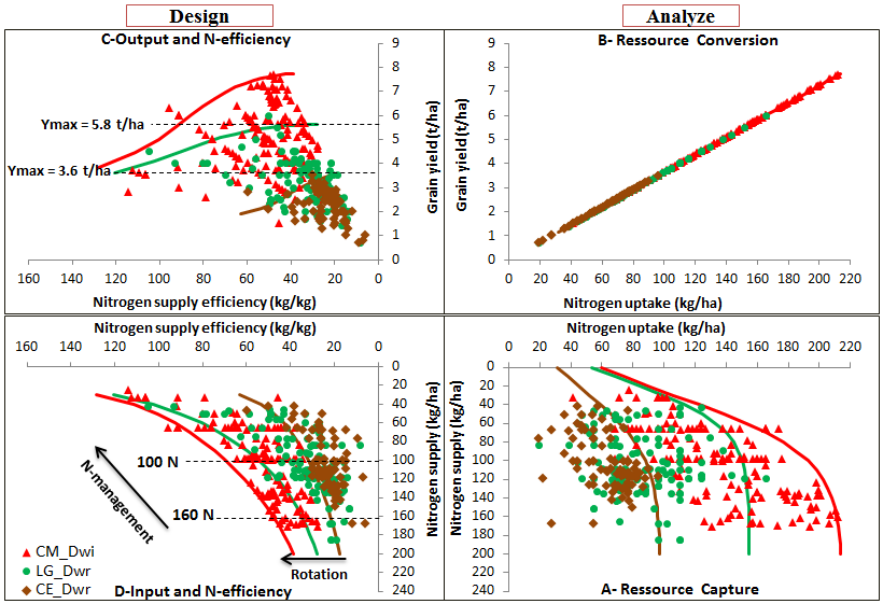

Figure 1.Four-quadrant diagram to analyze nitrogen efficiency according to rotation type:CM_Dwi: irrigated wheat after crop vegetable, CE_Dwr: rainfed wheat after cereals, LG_Dwr: rainfed wheat after legumes

Conclusions

This four quadrant framework allows to combine process-based (right part) and design oriented (left part) analysis of food production vs. resource use in cropping systems, making use of easy to access data in farmers fields. It showed the breakthrough which can be obtained in high production-low N input cereal-based systems through crop diversification and irrigation. Nevertheless the level and frequency of N absorption efficiency gaps for each preceding crop suggest that there are other crop management factors to be taken into account in farmers' fields.

References

De Wit C.T.: 1992. "Resource Use Efficiency in Agriculture. Agric. Syst., 40: 125–151.

Hochman, Z., et al.: 2013. Prospects for ecological intensification of Australian agriculture. Eur. J. Agron., 44: 109–123.

Keating, B.A., et al.: 2010. Eco-efficient Agriculture: Concepts, Challenges, and Opportunities. Crop Sci., 50: S–109–S–119.