ASSESSMENT OF NITROGEN FERTILIZATION IN TUNISIAN WHEAT PRODUCTION USING PROXIMAL AND REMOTE SENSING #11255

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ABSTRACT

The study aims to develop an approach and a workflow to optimize the in-season nitrogen (N) application in wheat cultivation in Tunisia, using the remote and proximal sensing techniques. Two types of trials, N response trials on small plots and large-scale trials, were carried out for two seasons (2023-2024) in the different climatic zones in the country. Data were collected for several parameters (e.g. N content, vegetation indices 'VIs', yield) and statistically analyzed. The preliminary results showed wide variations of data around the means and no significant differences, for the different parameters, between the N rates in the N response trials, even in the zero plot (no N added). The VIs were quickly saturated at early Growth stage (GS≈31-39), only the first measurement in February showed slight differences between the measurements of the different N treatments. The correlation between the N content and the VIs for the first date was weak (r2=0.2).

INTRODUCTION

Tunisia faces water scarcity, and the agricultural sector declines due to climate change, with projected decreases in rainfall, changes in rainfall pattern and increases in temperature (Ouessar et al., 2021; Mechri et al., 2023). Tunisian farmers face challenges in effective land management and optimal N fertilisation due to the crucial role of agriculture in Tunisia's economy and food security (FAO, 2023). N is one of the key nutrients that limit the crop growth of cereals in many production systems and is a key factor in achieving the optimum grain yield (Wang et al, 2023). The importance of N fertilization in increasing wheat production has been well recognized but still difficult to determine the quantities to apply under water deficit conditions (Kedir, 2020). The cereal sector in Tunisia covers wide areas in the country from sub-humid to semi-arid zones; where most of the fields are rainfed (Sadok et al., 2019). The Nutrients availability in the soil are induced elements in the soil, water shortage is tightly correlated to water management policy in the country that prioritizes allocating surface water to domestic uses rather than to irrigation. On the other hand, irrigation using groundwater (e.g. in Kairouan) continues to overuse the water table with an average drawdown of 5 m year-1. These conditions lead to a low N use efficiency, low national wheat (Triticum durum L.) average yield – estimated to 1.4 t ha-1, in addition to groundwater pollution (de Oliveira et al 2020). In Sweden, the zero plot technique to assess the initial soil N supply is widely used by farmers, often in combination with proximal sensing based digital tools for variable rate application (VRA) of N (Alshihabi et al., 2020). The risk of nutrients leaching is high during the after-harvest rainfall, in Sweden catch crops, is a measure commonly used to uptake the residual nutrients in between growing seasons, which is not applicable in Tunisia due to lack of rainfall during the summer season. In this study an experimental program was implemented in Tunisia to assess the N uptake using proximal and remote sensing for better N fertilizing practices.

MATERIALS AND METHODS

The present project (2023-2024), is a collaboration between the Swedish university of agricultural sciences (SLU) and two institutions in Tunisia (the National Institute of Field Crops 'INGC', and the National Agronomic Institute of Tunisia 'INAT'), it aims to develop basic knowledge, methods, calibration models and workflows for proximal and remote sensing in wheat production in Tunisia, to be used as the basis for a DSS for optimizing N recommendations to the wheat farmers. The project collaborates with a wider project on N application management (NUTCAT) covering several African countries. The joint research program in Tunisia covers all the climatic zones of cereal cultivation, the rainfed production in the sub-humid (e.g. Beja) and the semi-arid (e.g. Manouba and Siliana) areas, while irrigation is applied in the arid area in Kairouan. In each climatic zone, two types of trials were implemented in farmers' fields: N response trial on small plots (3×12m), and 2-3 larger trials (1 ha). The N response trials cover 15 different rates of N application (T1-15), which vary from 0 kg ha-1 for the zero plot in all areas, and for the fertilized plots varies from 20-80 kg ha-1 in the semi-arid area, 50-190 kg ha-1 in the sub-humid area to 70-280 kg ha-1 in the aridIrrigated area. The fertilization was carried on in 1, 2 or 3 doses (D1 pre-plant, D2 at growth stage 25 and D3 at GS 30). Although, the amount of added N varies from region to another, but it follows same strategy:

- _T1, for zero plots (no N added)
- _T2-5, only D1 varies increasingly from T2 to T5
- _T6-8, D1 same amount and D2 varies increasingly from T6 to T8
- _T9-11, D1 same amount, no D2 and D3 varies increasingly from T9 to T11
- _T12-15, D1 same amount, D2 same amount and D3 varies increasingly from T9 to T11

The large-scale trials are split into two parts (1 ha each), one for the optimal practices (OT) designed by INGC, and the second part is the farmer practices (FP). Data on soil properties, in season crop status, yield and grain quality, georeferenced vegetation indices (VIs) using simple radiometer proximal sensors (RapidScan CS-45, Holland Scientific, USA and Green Seeker handheld, Trimble, USA) and the chlorophyll meter (SPAD-502, Konica Minolta, Japan) were collected. The satellite images, mainly from Sentinel-2, were downloaded and correlated with the ground truth measurements and the proximal data in the OT and FP experiments. The approach and the workflow aim at developing two correlations, one between the ground truth N uptake and the VIs from the proximal sensors measured in the N response trials, the second is a correlation between the VIs measured from the proximal sensors in the large trials and those calculated from the satellite images. The data analysis is still ongoing, in this study only the statistical analysis, the ANOVA test (at 95% confidence level) results of the yield and the VIs in the different N response trials for the two seasons 2023-2024 and the correlation between the VIs and the N content for the year 2023 will be presented.

RESULTS AND DISCUSSION

The results showed a wide range of variations in the yield between treatments in the two years in all the climatic areas. The year 2024 was worse, in general, in term of yield except for the semi-arid area. The range of StDev was very high in the semi-arid area when compared to the means (70% of the mean in 2024, 90% in 2023), while it was below 50% for the sub-humid and arid irrigated areas (see Table 1). This can be explained by the severe shortage of water, where the variations are less when water is more available (the case for sub-humid and arid irrigated areas). The maximum obtained yield in the sub-humid and semi-arid didn't exceed 4 t ha-1, while the minimum values were very low (e.g. 0.14 kg h-1 in the semi-arid in 2023). In the Arid Irrigated area, the maximum yield reached 6.55 t ha-1, and the minimum obtained yield was 1.26 in 2023, the maximum yield in the year 2024 was lower than the maximum in 2023 but the lower yield was noticeably higher (3.1 t ha-1) as shown in table 1. The highness and the stability of the yield in this area, compared to the sub-humid and semi-arid areas, is attributed to the high N rate application and the irrigation.

Table 1. Descriptive statistic for the yield in the three regions for the two years.

Region	Year	Mean	StDev	Min.	Max
Sub-humid	2023	1.99 – 2.88	0.10 – 1.23	0.57 – 2.25	2.25 – 3.96
	2024	1.49 –2 .45	0.18 – 1.24	1.03 – 2.05	1.35 – 3.62
Semi-arid	2023	0.27 – 1.63	0.03 – 1.46	0.14 – 0.56	0.44 – 3.32
	2024	0.61 – 2.15	0.09 – 1.48	0.20 – 1.03	1.11 – 3.52
Arid (Irrigated)	2023	2.75 – 6.21	0.10 – 2.21	1.26 – 4.61	3.81 – 6.55
	2024	3.64 – 5.24	0.25 – 1.31	3.10 – 4.73	4.10 – 5.66

The zero plots (T1) showed comparable yield values to the other treatments in the two years at the three zones (this was obvious in the field visits at the different growth stages). Adding the total amount of the fertilizer at the pre-plant stage (T2-5) was slightly beneficial to the crop in term of final yield comparing to the other treatments (T6-15), no clear trend was noticed between the different N rates among T2-5 (Figure 1). Adding N at different amounts (2 or 3 doses) did not improve the yield in the different climatic zones for the two studying years. The ANOVA test showed no significance at confidence level 95% between the different treatments, including the zero plot (T1-15), for the different N rates and application strategy. This likely means that something other than N supply was more limiting for crop growth and development. In the non-irrigated trials, it may have been water (small crop N demand). In the irrigated trials, it may instead be due to a large soil N supply (large soil N supply). This shows that, in a farming situation, small on-farm trials, like zero N plots, may be useful for the farmer to understand the balance between soil N supply and crop N demand, and how much is the need for supplemental N fertilization. If the zero plot cannot be distinguished from the surrounding field, the local soil N supply is large enough for the current crop and one may consider saving on supplemental N fertilization (which would mean avoided cost and reduced risk of N leaching to the environment). If, on the other hand, the zero-plot shows symptoms of N deficiency, one may consider supplemental N fertilization, considering whether one expects otherwise favorable conditions such that the crop can use the additional N.

The statistical analysis gave the same result (no significance at 95% confidence level from ANOVA test between the different treatments T1-15) for the VIs (NDVI, NDRE) measured using the proximal sensors, the chlorophyll concertation measured using SPAD and the N concentration from the laboratory analysis. The VIs were saturated (reached maximum values NDVI≈0.93, NDRE≈0.43) in end of February (GS≈31-39). The crop growth goes very fast in the month of

February and varies between the climatic zones. The VIs values were lower in March because of the progress to the heading growth stages (GS≈50-58). The correlation between the N content and the VIs for the measurements taken in 24th February 2023 was weak (r2=0.2), the correlation was not studied for the later measurements because of the saturation in VIs' values.

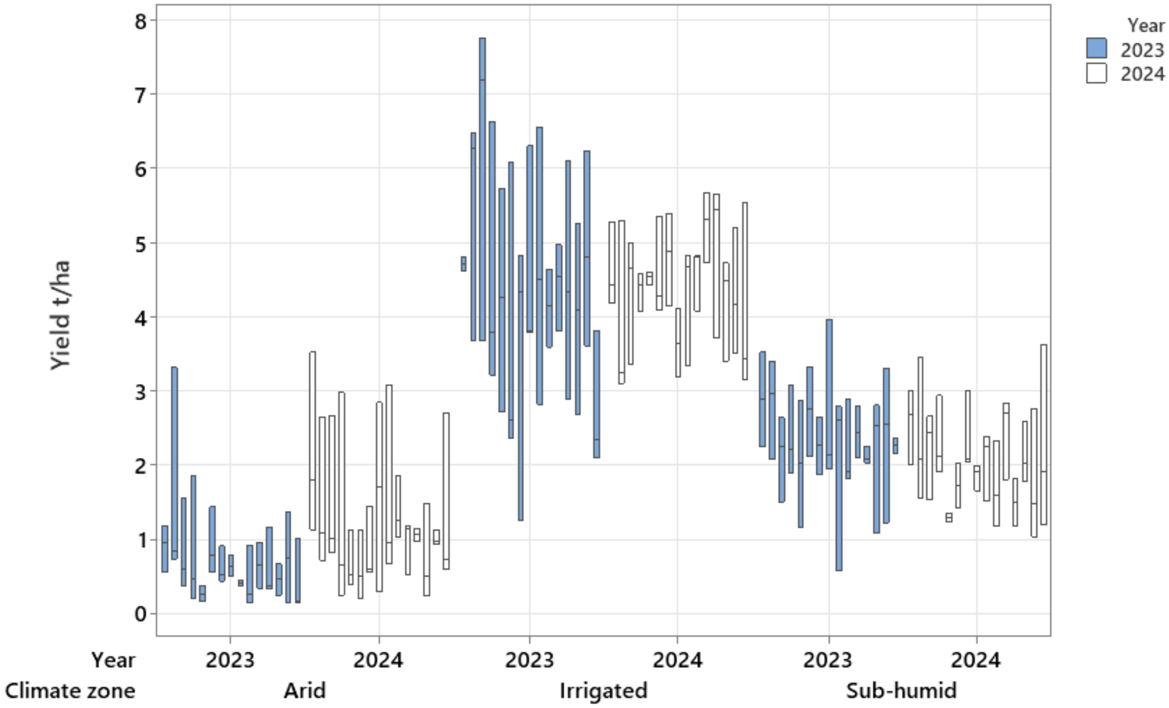

Figure 1. Yield in t ha-1 (2023,2024), N response trials by climate zone, T1-15 from 0 N kg ha-1 (T1, the one on the left of each group) to 80-280 N kg ha-1 (T15, the one to the right of each group).

The preliminary obtained results in this project showed, for the three climate zones and the two successive years, there is a need to assess the soil N supply from the previous season as a vital measure to optimize the N management in term of amount and timing. Simple technics can be adopted in the farmers' fields, like the zero plot, to detect the plant-available N storage in the soil, the technique is easy enough, that the farmer can apply several zero plots in his field to detect the within field variations for precision agriculture practices.

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