Analysis and diagnosis of nitrogen nutrition in durum wheat for the design of a nitrogen fertilizer grid in the semi-arid region

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Abstract. Improving the efficiency of nitrogen use by crops has become imperative in the current and future economic and environmental context. Nitrogen fertilization is often considered as the practice with the greatest impact on crop growth. However, optimizing its management is highly dependent on soil conditions and intra- annual climatic achievements. The fractionation of nitrogen fertilizer inputs is a relevant approach to better match crop needs with nitrogen supplies. Nitrogen fertilization strategies that combine the fractionation of the total recommended agricultural plot-scale with the assessment of the nitrogen requirement during the growing season can greatly help to better match nitrogen requirements and supplies. This will increase the efficiency of nitrogen use of the applied fertilizer. The final objective of these strategies is to assist in deciding whether to apply complementary nitrogen fractions and how much nitrogen to apply. It may be easier to look at the crop itself as an indicator of its nitrogen requirement. In fact, the biomass produced is often considered to integrate well the effects of conditions occurring during the growing season. The objective of this work carried out over several years on several sites in different regions where we have chosen, in this article the site of the region of El-outaya for a single 2016/2017 agricultural campaign, is to study the effects of different fractionation of a rate of 69 NU per hectare on aerial biomass, 1000 grain weight, grain yield, grain protein content, dry matter nitrogen content and chlorophyll content durum wheat to establish a nitrogen fertilizer grid in the semi-arid region. The results obtained showed highly significant effects on all the parameters studied. This study confirms that a dose of 69 units of nitrogen, applied in two fractions (Df) distributed 2/3 at tillering and 3/4 at the stage of 1cm spike improves all the parameters studied compared to the control (Dt) and the dose made in the tillering stage (D0). The chlorophyll content recorded in (Df) indicates that the plant is well fed with nitrogen, so it is not interesting to use another fraction of nitrogen, knowing that the protein is not valued at this time in Algeria.

Keywords. Nitrogen fertilizers - Chlorophylls - Nitrogen fractionation - Semiarid zones - *Hard wheat*.

Analyse et diagnostic de la nutrition azotée du blé dur pour la conception d'une grille de fertilisation azotée, en région semi-aride

Résumé. *L'amélioration de l'efficience d'utilisation de l'azote par les cultures est devenue impérative dans le contexte économique et environnemental actuel et à venir. La fertilisation azotée est souvent considérée comme la pratique ayant le plus grand impact sur la croissance des cultures. Cependant, l'optimisation de sa gestion est fortement dépendante des conditions de sol et des réalisations climatiques intra-annuels. Le fractionnement des apports d'engrais azotés est une approche pertinente pour une meilleure adéquation entre les besoins de la culture et les fournitures en azote. Les stratégies de fertilisation azotée qui combinent le fractionnement de la dose totale recommandée à l'échelle de la parcelle agricole avec l'évaluation du besoin en azote en cours de saison culturale peuvent aider largement à mieux faire coïncider les besoins et les fournitures en azote. Il en résultera un accroissement de l'efficience d'utilisation de l'azote de l'engrais appliqué. Ces stratégies ont pour objectif final d'aider à la décision quant à la nécessité d'appliquer des fractions complémentaires d'azote et à la quantité d'azote à appliquer. Il peut être plus simple de s'intéresser à la culture elle-même comme indicatrice de son besoin en azote. La biomasse produite est en effet souvent considérée comme intégrant bien les effets des conditions apparaissant durant la saison de croissance. L'objectif de ce travail réalisé sur plusieurs années sur plusieurs sites dans différentes régions où nous avons choisi, dans cet article le site de la région de El-Outaya pour une seule campagne agricole 2016/2017, est d'étudier les effets de différentes modalités de fractionnement d'une dose de 69 unités d'azote par hectare sur la biomasse aérienne , le poids de 1000 grains, le rendement en grains, la teneur en protéines du grain, la teneur en azote de matière sèche et la teneur en chlorophylle du blé dur afin d'établir une grille de fertilisation azotée en région semi-aride. Les résultats obtenus ont montré des effets hautement* *significatifs sur l'ensemble des paramètres étudiés. Cette étude confirme qu'une dose de 69 unités d'azote, appliquée en deux fractions (Df) réparties 2/3 au tallage et 3/4 au stade épi 1cm améliore tous les paramètres étudiés par rapport au témoin (Dt) et la dose apportée en totalité au stade tallage (D0). La teneur en chlorophylle enregistrée dans (Df) indique que la plante est bien alimentée en azote, donc il n'est pas intéressant de faire recours à une autre fraction d'azote, sachant que la protéine n'est pas valorisée à ce jour en Algérie.*

Mots-clés. *Engrais azotée - Chlorophylle - Fractionnement azoté - Zone semi-aride - Blé dur.*

I - Introduction

In Algeria, much of the land in the semi-arid regions is occupied by cereals, whose yields remain low and irregular. The inability of Algeria to self-sufficiency in this commodity remains unusual given the areas planted. *A priori*, it is the low yields observed that make the production still shy, when some developed countries easily reach the average yields of 45 q/ha, Algeria is nearing a national average of 15q/ha in the best years (ONIGC, 2007). Cereal production has become a worrying issue for Algeria, whose needs for a growing population are estimated at more than 111 million quintals by 2020 (Hervieu *et al.*, 2006). In this context, managers are interested in increasing cereal yields and are faced with the imperative need to optimize farming techniques including mineral fertilization and especially nitrogen fertilization. The improvement of the yield of the strategic crops of the country should be obtained by a better management of the inputs of which the nitrogen fertilizer, doses and fractionation, and the application of this nitrogen following the characterization of the grounds. But this control cannot be assured without the knowledge of the mechanisms involved in the supply of nutrients for plants, especially in semi-arid zones. Although the low yields are largely due to the cultivation techniques used and the plant material used, many studies agree that the weakness and instability of production are related to the irregularity of rainfall, associated with the strong temperatures, especially at the end of the cycle where the potential rate of accumulation of nitrogen is a function of the temperature.

In Algerian areas of good cereal production potential where farming techniques are recommended, the average yield can reach 15q/ha, with peaks of 50q/ha. It is advisable in this region, an application of the two nutrients (N and P2O5) of 50 to 100kg/ha. Nevertheless, this dose remains below the needs of cereals.

The program for improving the use of fertilizers in cereal crops is to introduce tools for controlling nitrogen fertilization. There are tools for readjustment during the season that refine the control of nitrogen fertilization at the conditions of the year. These nitrogen nutrition indicators are defined as revealing variables of the level of nitrogen status of the crop. A range of tools and methods has been tested. Examples of these tools are the Jubil method, INN, nitrachek, SPAD and Crop Scan.

II - Materials and Methods

The experiment was conducted during the 2016/2017 crop year in the open field, on a parcel at a private farmer, non-cultivated over five successive years. The climate of this campaign (2016/2017) was characterized by insufficient rainfall with a sum of 255.8 mm. However, it should be noted that neither the temperatures above 25°C coinciding with the harvest likely to cause physiological accidents on the wheat culture (scalding), nor those minimum negative (-5° C) feared for their destructive action on seedlings after emergence (Gate, 1995) caused visible damage. The plant material is durum wheat with the variety Waha which is an introduced variety of Syrian origin. This variety is characterized by its good behavior and ability to produce in semi-arid areas (Boufenar-Zaghouane and Zaghouane, 2006).

Physio-chemical analyses carried out at three depth levels indicate that, on average, the soil of the test plot has a clay-silty texture (32.9% clay) with a total limestone content of 38%, the experimental soil is alkaline (ph = 7.5) with a level of 6.2% organic matter. The adopted experimental device is a device in total randomization, comprising three (03) levels and four (04) repetitions. Each elementary parcel has dimensions of 03 m long and 1.5 m wide. The basic plots are devoted to the different methods of fractionation of nitrogen fertilizer which is urea 46%, and the spreading was done manually. The different types of fertilizer applied are the following two fractions of nitrogen fertilizer (Df) distributed in 2/3 at tillering and 3/4 at the 1cm ear stage, a single intake of the total dose at the tillering stage (Dt) and one witness without input (D0). The measurements concerned the following parameters: aerial biomass, 1000 grain weight, grain yield, grain protein content, nitrogen content of mature aerial biomass and chlorophyll content.

The choice of this dose was based on the dose experienced during several years of study which is 150 kg of urea/ha or 69 units of nitrogen/ha. In the same way, the choice of the stages of intake were according to the fractionation modalities experimented during several years of study. Soil preparation was limited to deep plowing using a plow followed by two crossed passages to cover crop were made on 15/11/16. Seeding was carried out on 27/01/2017 (late) by an in-line seeder at a depth of 4 cm. The seeding rate is 140 kg / ha. Weeding was applied at the early tillering stage by a Knight systemic weed killer at a rate of 4 kg ai/ha. Supplemental irrigation was carried out by sprinkling with a frequency of 12 inputs during this campaign, which was marked by a water deficit during the months of February until May. The parameters measured at the heading stage are the total chlorophyll content of the leaves made by the chlorophyll-meter CCM-200 directly in the fields (Nouri, 2002), on the penultimate leaf of the master strand. It is expressed in SPAD unit. A sample of 10 ears per elemental plot measured the weight of a thousand grains. The harvesting was done manually on the 27/05/2017 for a 50 cm mowing of the mature seedlings in each elementary parcel, allowing us to measure the above-ground biomass, and the grain yield per unit area. The results obtained were statistically processed using the excel stat 2009 software using the Newman and Keuls test (at the 5% threshold).

III - Results and discussion

1. Effect of nitrogen fertilization on aerial biomass production of straw

According to Figure 1, the supply of 69 units of nitrogen/ha units when divided into 2 inputs significantly improved ($P < 0.0001$) the vegetative dry biomass of straw where we recorded a significant production of dry matter straw (49.43q/ha) compared to those of a single intake and without nitrogen supply which are of the order of 45.34q/ha and 41.07q/ha. This shows that the production of aerial dry matter has been favored by the good supply of nitrogen plants. According to Gate (1995), to obtain a high biomass, it is necessary to mobilize large quantities of nitrogen, since a nutritional deficiency will have a very penalizing effect on the aerial biomass at maturity. The same author obtained a greater accumulation of dry matter in the aerial part after doubling the nitrogen dose. He indicated that the aim of the tillering phase is to promote yield and a late intake favors the protein content. Thus, a fractionated intake, must be able to both maintain the yield and increase the protein level. Billy, (2008) reports that tillering, providing nitrogen at the time when the plant needs it most, seems more relevant. These results are also confirmed by other studies, such as that of Sieling *et al.* (2005), on the growth and yield of winter wheat subjected to a series of nitrogen treatments or Sieling *et al*. (2006). that showed the effect of nitrogen on the growth of rapeseed, wheat and barley in Germany, showing that the support of grain production (vegetative biomass) was closely dependent on nitrogen nutrition. For example, Girard (1997) reported that dry biomass results mainly from the conversion of radiation during photosynthesis, the unfolding of which is influenced by nitrogen. The potential for converting radiation into biomass varies with the phenological stages of the crop since each stage has its own nitrogen requirements which suggests a nitrogen fertilization fraction. Our findings on the importance of tillering nitrogen fractionation on air dry matter production, demonstrated in our investigation, are consistent with those of Ehdaie and Waines (2001) subtracted from the comparison of the effects of variation in sowing dates and nitrogen fertilization on dry matter production in five durum wheat genotypes. According to Gate (1995), to obtain a high biomass, it is necessary to mobilize large quantities of nitrogen, since a nutritional deficiency will have a very penalizing effect on the aerial biomass at maturity. Gate (1995) which obtained a greater accumulation of dry matter in the aerial part after doubling the nitrogen dose. As Semenov et al. (2007), the fractionation of nitrogen fertilization with inputs at Zadok stages 23, 30 or 23, 30 and 39 significantly increases yields in quantity and quality.

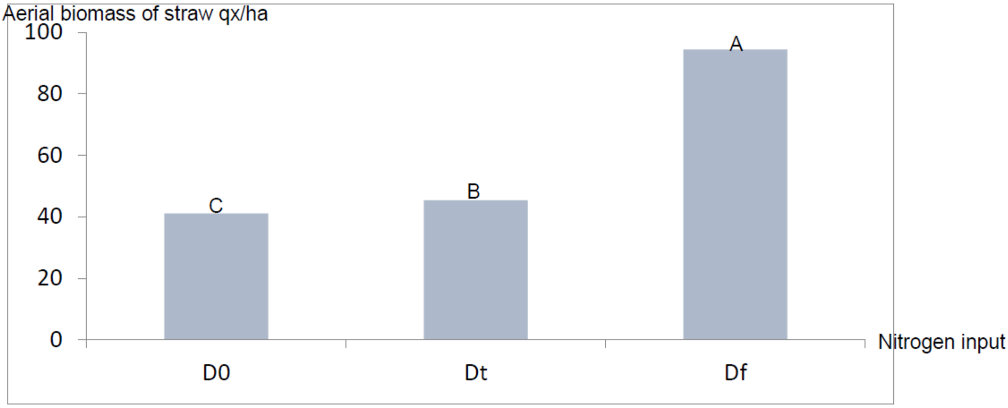

Figure 1. Average values of aerial biomass in durum wheat according to the different nitrogen input modes.

2. Effect of fractionation of N fertilizer on TGWand grain yield

We noted a significant increase in the weight of 1000 grains with the fractional dose (Df), a gain of 8.35q/ha was recorded by input to the unfertilized control. The same result is noted for grain yield with a gain of 19.94q/ha (table 1). A similar result was observed by Mandic et al (2015) who showed that nitrogen fertilization improved wheat TGW. The advantage of the distribution of nitrogen manure in several inputs can be explained by the fact that its application covers the nitrogen requirements of the two critical vegetative stages of wheat. These results were also demonstrated by Lόpez Bellido et al. (2005) who worked on the response of a variety of bread wheat to a nitrogen fertilizer applied in three inputs. The same conclusion was affirmed by Kratochvil *et al*. (2005). Wang et al. (2013) confirmed that nitrogen fertilization promotes a significant improvement in grain yield of wheat, which is explained by good root development of wheat. The same quantity of nitrogen can have different impacts on the yield and even the quality of the grain, depending on the stage of the fodder vegetation, corresponding to the formation of one or other of the grain yield components (Coïc, 1956). The first contribution of 1/4 of the needs and the second largest of 3/4 of the needs, practiced successively at the beginning tillering and 1cm spike ensure a high biomass and therefore the future stand in spike, as has been reported by Ewert and Honermeier (1999). This stand in spike that is represented by tillering spike/foot and even spikelets/spike. These two contributions coincide with the establishment of these components, which begin at the beginning tillering and end at mid-run (Meynard, 1985). The interest of a high proportion of nitrogen at the 1cm spike stage is in agreement with the conclusions of Sieling *et al.* (2005) who show that this phase of the vegetative cycle is the one that needs nitrogen most to ensure the run and a good tillage spur. The latter improves following the attenuation of the phenomenon of regression of the tillers by the dose (50%) of nitrogen fertilizer (Darwinkel, 1983). Similarly, Randall *et al*. (2001) have noted that a nitrogen influx at about five tillers provides a suitable stand while creating in the crop subsequent needs that must be met by a second one. intake at the stage early run. The advantage of the distribution of nitrogen fertilization in several contributions was also demonstrated by Kratochvil *et al*. (2005) and especially by Lǿpez-Bellido et al. (2005) who studied the response of a wheat variety. tend to a nitrogen fertilization of 150 units/ha applied in 3 contributions intended for the stages sowing, tillering and early start. The strong improvement in grain yield related to the 50% supply of needs at the 1cm spike stage, obtained with both the 2 and 3 fractions modality, is also observed by LǿpezBellido *et al*. (2005), affecting 1/3 at 1/2 of the total dose at stage B (early run). Brown and Petrie (2006) also came to the same conclusion.

Table 1. Average values of TGW (g) and grain yield (q/ha) in durum wheat according to the different methods of nitrogen input.

Nitrogen input	Weight of 1000 grains in (g)	Grain yield (q/ha)
D0	41.07 C	22.14 C
Dt	45.34 B	24.51 B
Df	49.42 A	42.08 A
P	P<0.0001 ***	P<0.0001 ***

*P: degree of significance Different capital letters (A, B, C) in the same line indicate the index of separation of the homogeneous groups by the NEWMAN-KEULS test at the threshold α = 5%. Threshold of significance: P <0.0001. *: Significant difference; **: Very significant difference; ***: Difference very highly significant.*

3. Effect of nitrogen fertilization on protein and nitrogen content of straw in durum wheat

Table 2 shows that the fractionation of nitrogen fertilizer significantly enriched the grain protein and increased the accumulation of nitrogen in the plant mass. In fact, the supply of 69 units of nitrogen in two fractions (Df) has greatly improved the level of proteins compared to the supply of the same dose of nitrogen at one time (Dt) and without intake (D0) and protein levels were 12.14, 9.92% and 9.76%, respectively. Regarding the nitrogen content of the dry matter of the straw, the bipartite (Df) modality is more enriching than that of a single intake (Dt). Its biomass contains 1.27% against 0.87%. On the other hand, the control without nitrogen supply (D0) produces an aerial biomass less rich in nitrogen which is of the order of 0.77%. Our results are in total agreement with those of Farrer et al (2006) who showed that the fractionation of the nitrogen dose improves the protein content of wheat up to 51.4%. In the same thread of idea Pan *et al*. (2006) confirmed that nitrogen input leads to an improvement in the nitrogen content of vegetative dry matter and protein in the grain produced. The latter are the main quality parameter of the grain, and in direct relation with the type of nitrogen fertilization It is also when the nitrogen requirements are divided into 2 or even better in 3 inputs that the wheat culture absorbs the element better. nitrogen and produces a richer grain of protein (Clark and Ellsworth, 2004). Limaux (1999) and Latiri-Souki *et al*. (1992) have shown that durum wheat grown in the semi-arid zone of Tunisia, the more nitrogen fertilizer is fractionated (especially in the early tillering and early start stages), the more it is valued and its grain is richer in protein. In another study conducted by Farrer *et al*. (2006), they showed that the intake stage and the nitrogen dose (Fractionation effect), contribute with 51.4% in the variability of the protein content of wheat. According to these authors, stage B (early start) increases the protein rate more than tillering (5 tillers in their experimental conditions). These results are consistent with our results. As for the production of vegetative biomass, tails spike/foot, TGW and finally grain yield / ha, massive intake of 50% of nitrogen requirements at the 1cm spike stage, accompanied by low doses of 25% at early tillering and at the 2-node stage is the most optimal nitrogen fertilization model for the nitrogen supply of wheat and the richness of its grain protein. At this level again, the nitrogen dose reserved for the 1cm spike stage is decisive for the nitrogen content of vegetative biomass and grain.

Lemaire and Gastal (1997) yielded similar results derived from monitoring growth and nitrogen accumulation by isolated plants, by studying growth, water use, and water accumulation. nitrogen by wheat in Mediterranean conditions, Garabet *et al*. (1998) reached the same conclusions. In the end, nitrogen assimilation of wheat (before and after flowering) remains the main source of protein at the grain level (Vocanson, 2002). Nitrogen fractionation allows the good valorization of the various inputs, the improvement of the nitrogen content of the different vegetative parts and a good remobilization of this nitrogen towards the grain produced (Martre *et al*., 2003).

Table 2. Average values of grain protein content and nitrogen content of straw in durum wheat according to the different nitrogen input modes.

Nitrogen input	Grain protein content (N% MS * 5.7)	Nitrogen content (g of N / 100g of dry matter
D0	**9.76** **B**	**0.77** **C**
Dt	**9.92** **B**	**0.87** **B**
Df	**12.14** **A**	**1.27** **A**
P	P<0.0001 ***	P<0.0001 ***

*P: degree of significance Different capital letters (A, B, C, D) in the same line indicate the index of separation of the homogeneous groups by the NEWMAN-KEULS test at the threshold α = 5%. Threshold of significance: P <0.0001. * : Significant difference ; **: Very significant difference; ***: Difference very highly significant.*

4. Effect of fractionation of nitrogen fertilizer on leaf chlorophyll content in durum wheat

The chlorophyll content of the leaves was distinguished by a significant increase in the fractional nitrogen dose (Df) compared to that of Dt and D0 (Figure 2). This increase could be attributed to the location of the majority of the nitrogen in the chlorophyll molecules, this has been demonstrated by Moughli (2010) indicating that there is a good correlation between the chlorophyll content of the leaf and its content. in nitrogen. In this modality the plants are rich in nitrogen which allows us to decide not to bring another fraction of nitrogen, knowing that the protein is not valued to date in Algeria. These results are confirmed by Menad and Ould-Said (2003) who find that a plant that is well fed with nitrogen produces a large vegetative mass of dark green color due to the abundance of chlorophyll.

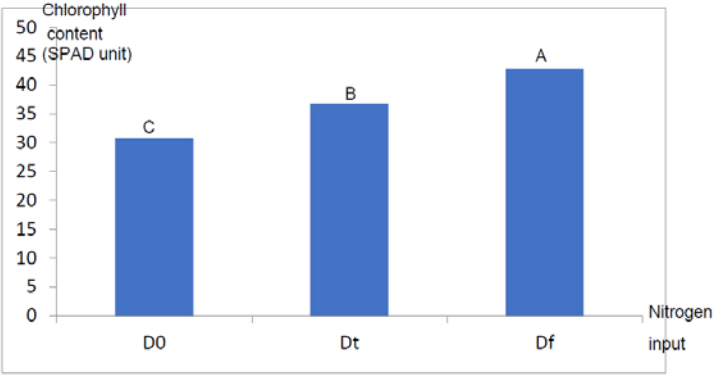

Figure 2. Increase in the chlorophyll content according to different nitrogen input modes.

IV - Conclusions

The present work shows the use of a decision support system for the optimization of nitrogen fertilization. The tool in question relies on whether or not the plant has nitrogen at a given moment (heading stage) of different nitrogen fractionation modalities. It also offers the user the ability to manage his own nitrogen fertilization.

Through the results obtained, we have been able to deduce that the dose divided into two inputs (Df) 1/4 at tillering and 3/4 at the 1cm stage of nitrogen significantly improved all the parameters studied for durum wheat, namely the aerial biomass of straw, straw nitrogen content, grain protein content, 1000 grain weight, grain yield versus total tillering dose (Dt) and control dose (D0) without input. The chlorophyll content of this dose confirms the favorable effect of split intake (Df) with a higher content of about 42.86 units of SPAD.

However, these conclusions are limited to the fact that the protein is not valued to date in Algeria.

Finally, nitrogen fertilization is often considered the practice with the greatest impact on crop growth. However, optimizing its management is highly dependent on soil conditions and intra-annual climatic achievements.

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