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Research Article

Study of the effect of water stress and nitrogen dose on six Moroccan varieties of soft wheat

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Abstract *–*The aim of this investigation is to evaluate the impact of varying nitrogen dosages and irrigation levels on diverse agronomic parameters, including tiller count, biomass, yield, and associated components. In response to this inquiry, a field trial was executed at the Sidi El Aidi Experimental Station of the INRA in Settat. Three nitrogen treatments were administered across two distinct hydric regimens. The initial treatment set (N0= 15 kg/ha; N1=60 kg/ha; N1= 120 kg/ha) was implemented under rain-fed conditions, whereas the subsequent set (N0= 15 kg/ha; N1=100 kg/ha; N2= 200 kg/ha) was applied under irrigated conditions. These treatments were systematically evaluated across six varieties of soft wheat (Malika, Achtar, Snina, Kharouba, Amal, Arrihane).

The outcome of the study delineate that both irrigation and nitrogen fertilization exert a statistically significant and positive influence on pivotal agronomic parameters, including tiller count per plant, biomass accumulation, grain yield, and key yield components such as grains per square meter and thousand-grain weight. Notably, the Snina variety manifested the utmost tiller count, averaging 8.7 under the highest nitrogen dosage (N2) within irrigated conditions. Furthermore, the Achtar variety exhibited the highest grain yield, registering 48.46 quintals per hectare under the influence of the N2 nitrogen dosage. The results underscore the nuanced responses of different varieties to water and nitrogen inputs, underscoring the imperative consideration of specific varietal traits in the context of fertilizer and irrigation management. It is imperative to highlight that additional parameters, such as water use efficiency (WUE) and nitrogen use efficiency (NUE), warrant further in-depth investigation to ascertain varieties demonstrating heightened proficiency in resource utilization.

Keywords –Nitrogen Fertilization, Soft Wheat, Tillers, Grain Yield, Biomass.

Introduction:

Cereals play a crucial role in the global agricultural system, serving as a primary source of nutrition for both humans and animals (Slama & al., 2005). Among these cereals, wheat stands out as one of the oldest species and a significant component of human diet, contributing to its substantial economic importance. However, wheat production requires meticulous care, precision in procedures, and advanced technical skills.

Environmental stresses, particularly water stress, significantly limit plant growth and vegetative productivity (Wang et al., 2003). Water scarcity, often coupled with other abiotic stresses like frost, high temperatures, salinity, and the variability of climatic factors, leads to substantial yield losses. Water scarcity is currently a critical issue, guiding irrigation techniques toward more economical practices. Consequently, wheat cultivation remains threatened by irregular rainfall, depending not only on its quantity but also on frequent episodes of critical water deficit during the vegetative cycle.

After water, nitrogen fertilization is a key element in intensifying cereal production. It plays a crucial role in the plant and remains a limiting factor in increasing production, provided that other factors are optimal (climate conditions, cultivation techniques, etc.). Climatic variability, especially in rainfall during the growing season, makes nitrogen fertilization of cereals a delicate practice. Insufficient nitrogen doses are underutilized by the plant, limiting its productive potential. Conversely, supra-optimal inputs lead to high water consumption, particularly early in the cycle, with the filling phase occurring under water stress.

To ensure high yields, there is a need for optimal agronomic practices. This includes stricter management of nitrogen fertilization, adapting inputs to the needs of the crop at different developmental stages (Justes, 1993). This strategy, beginning with the analysis of the causal relationship between nitrogen absorption and final grain yield (Limaux, 1999), aims to assist cereal farmers in more effectively managing nitrogen inputs.

Currently, wheat improvement programs focus more on genetically enhancing tolerance to water stress. This improvement requires studying, identifying, and verifying phenological, morphophysiological, and biochemical traits related to yield under water stress conditions (Pfeiffer & al., 2000).

This study aims to examine the effect of different nitrogen doses on the evolution of tiller number, biomass, yield, and its components in six varieties of soft wheat (three old and three new). This work is part of a long-term study that encompasses various conditions and factors influencing the productivity and quality of Moroccan soft wheat.

Materials and Methods:

An experiment was conducted during the agricultural season in the field at the Sidi El Aidi experimental station, affiliated with the Regional

Center for Agricultural Research in Settat. The trial site is located in a semi-arid zone, 16 km north of the city of Settat, characterized by:

- Cold winters
- Irregular rainfall
- Hot and drying winds at the end of the plant's cycle

Plant Material Used:

The plant material consists of six varieties of soft wheat (Triticum aestivum).

Table 1: Name and Characteristics of the Varieties Used

Code	Name	Characteristics	Year of Registration
V1	Malika	New	2014
V2	Kharouba	New	2010
V3	Snina	New	2017
V4	Arrihane	Old	1996
V5	Achtar	Old	1988
V6	Amal	Old	1993

Experimental Setup:

The trial covers an area of 810 m² under two water regimes (Rainfed and Irrigated). It is designed as a "Split-plot" experiment with two factors (variety (V) and nitrogen dose (N)), with 3 repetitions (blocks), each block containing 15 elementary plots. The elementary plot consists of 6 rows, each 5 meters long, with a spacing of 0.18 meters. The plot's surface area is thus calculated as: 6 * 0.18 * 5 = 5.4 m².

Tree nitrogen doses were applied to each water regime according to the following table:

Table 2: Nitrogen Application for the Agricultural Season (Rainfed)

Nitrogen Dose	Base (kg/ha)	1st Application (Rainfed)	1st Application (Irrigated)	2nd Application (Rainfed)	2nd Application (Irrigated)	Total (Rainfed)	Total (Irrigated)
N0	15	0	0	0	0	15	15
N1	15	20	40	25	45	60	100
N2	15	45	85	60	100	120	200

Studied Parameters:

- **Morphological Parameters:**

Number of Tillers:

The number of tillers was measured on eight randomly selected plants in the four central rows of each plot. These plants were labeled after the initial count to track the evolution of the number of tillers on the same plants throughout the plant's entire cycle. Tiller counting was conducted every week or every two weeks from emergence until the late tillering stage, time and resources permitting. At the tillering stage, monitoring of the number of shoots for each plant was re-established every week until the late tillering stage.

- **Physical parameters**

Total Biomass:

To measure the biomass, a sample of 2 rows, each 1 meter in length, was cut at ground level in each elementary plot. The samples were collected in plastic bags labeled with the plot number. Biomass was then determined by weighing the samples (ears + straw) obtained from each plot.

Yield and its Components:

Yield is the most important parameter in this study. However, it is a complex trait to analyze and improve.

To obtain the yield, the rest of the elementary plot is harvested using a dedicated experimental combine harvester designed for harvesting small trial plots. The obtained grains are then weighed. Thus, the final yield (entire plot) is obtained by adding the yield of the plot to the yield of the sample taken before harvest.

Results and Discussion:

Effect of Nitrogen Dose on Tiller Number

Rainfed *(Bour)*

The analysis of variance (ANOVA) revealed significant to highly significant differences among varieties for all tiller counting dates. However, the differences were significant to highly significant among nitrogen doses for all dates except the tiller count on February 12, 2020. On this date, all nitrogen doses tended to have the same number of tillers. Table 3 shows the F probabilities for each date and the factors: variety, nitrogen dose, and the interaction V X N.

Table 3: Results of the Analysis of Variance for Tiller Number in Rainfed (Bour)

F Pr.	23-Jan	6-Feb	12-Feb	3-Mar	10-Mar
Variety (V)	0.006	<.001	0.016	<.001	<.001
Nitrogen Dose (N)	<.001	0.015	0.059	0.040	<.001
V X N	0.886	0.302	0.115	0.217	0.01

***: very highly significant (p<0.001), *highly significant (p<0.01), : significant (p<0.05), NS: Not significant*

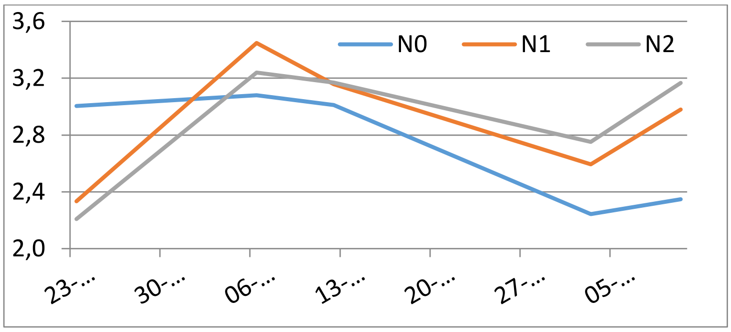

Figure 1: Variation in Tiller Number under Different Nitrogen Doses (N0, N1, and N2) in Rainfed

Under nitrogen doses N1 (60 kg/ha) and N2 (100 kg/ha), there is a similar trend in the number of tillers per plant. It increases from 2.33 on the first date to 3.45 on the second date. As with dose N0, the highest number is recorded on this date (February 6) and starts to decrease for the other dates for N1. For dose N2, the number of tillers increased on average from 2.21 (first date) to 3.24

(second date) before continuing to decrease due to competition between tillers. For both doses N1 and N2, Davidson and Chevalier (1989) explained these differences in development speed by the fact that the plant requires a certain time to acclimate to the water stress conditions to which it is exposed.

Irrigated

ANOVA revealed significant to highly significant differences among varieties for all tiller counting dates except on February 6. However, the differences were significant to very significant among nitrogen doses only for the dates on February 13 and 21. On other dates, all nitrogen doses tended to have the same number of tillers. Table 4 shows the F probabilities for each date and the factors: variety, nitrogen dose, and the interaction V X N. A very highly significant effect ($p<0.001$) is noted for the date on February 27.

Table 4: Results of the Analysis of Variance for Tiller Number in Irrigated

F Pr.	6-Feb	13-Feb	21-Feb	27-Feb	11-Mar
Variety (V)	0.759	0.003	0.002	<.001	<.001
Nitrogen Dose (N)	0.105	0.006	0.022	0.101	0.309
V X N	0.756	0.450	0.248	<.001	0.435

***: very highly significant ($p<0.001$), *: *highly significant* ($p<0.01$), *: significant* ($p<0.05$), *NS: Not significant*

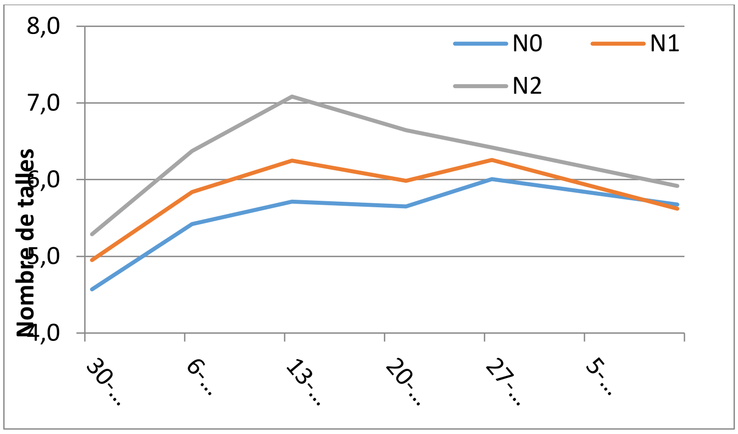

Figure 2 : Variation du nombre de talles sous les différentes doses d'azote N0, N1 et N2 en Irrigué

Under nitrogen doses N1 (60 kg/ha) and N2 (120 kg/ha), there is an increase in the number of tillers per plant with the increase in nitrogen dose. The number of tillers increases from 5 on the first date to 6.3 on the third date for dose N1. For dose N2, the number of tillers increased on average from 5.3 (first date) to 7.3 (third date) before continuing to decrease due to competition between tillers.

Effect of Nitrogen Dose on Yield Parameters

Bour

- Biomass

The ANOVA for biomass revealed significant effects ($p<0.05$) of the variety factor and highly significant effects ($p<0.001$) of the nitrogen dose factor. However, the variety x nitrogen dose interaction was not significant. All varieties behaved similarly to different nitrogen doses.

Table 5: Results of the Analysis of Variance for Biomass in Rainfed (Bour)

Source	**Df**	**SS**	**MS**	**VAR**	**F Pr.**
Block	2	14.86	7.43	0.10	
Variety	5	1034.56	206.91	2.66	0.039*
Nitrogen Dose	2	3155.88	1577.94	20.29	<.001***
Variety x Nitrogen Dose	10	2345.98	234.60	3.02	0.008**
Error	34	2643.96	77.76		
Total	53	9195.24			

***: very highly significant (p<0.001), *: *highly significant (p<0.01), : significant (p<0.05), NS: Not significant*

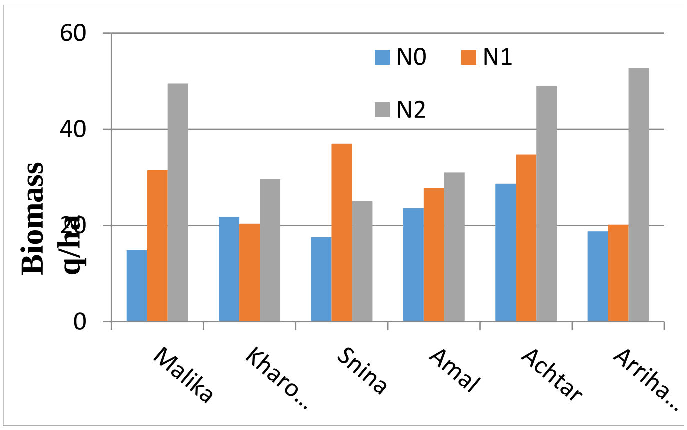

Figure 3 : Effect of nitrogen dose on Bour biomass.

The N2 seeding dose (the highest dose) resulted in the highest biomass for all six varieties studied compared to N0 and N1, except for the Snina variety, where N1 gave the highest biomass. Under the N2 dose, the Arrihane variety yielded the highest biomass (52.8 q/ha), followed by the Malika variety (49.5 q/ha) and the Achtar variety (49.1/ha). The lowest biomass at this nitrogen dose was recorded for the Amal and Kharouba varieties with 31.0 q/ha and 29.6 q/ha, respectively.

According to Gate (1995), to achieve high biomass, significant amounts of nitrogen must be mobilized because nutritional deficiency will have a very penalizing impact on aboveground biomass at maturity. Gate (1995) obtained a more significant accumulation of dry matter in the aboveground part after doubling the nitrogen dose.

- <u>Grain Yield</u>

For the 2019/2020 season, the ANOVA for the Sid El Aidi station revealed a highly significant effect (p<0.01) for the variety factor and a significant effect for the seeding dose factor. Furthermore, the interaction between the variety and nitrogen dose factors revealed very highly significant differences.

Table 6: Results of the Analysis of Variance for Grain Yield in Rainfed (Bour)

Source	**Df**	**SS**	**MS**	**VAR**	**F Pr.**
Block	2	24.59	12.30	0.40	
Variety	5	1026.19	205.24	7.56	<.001***
Nitrogen Dose	2	212.45	106.23	3.91	0.030*
Variety x Nitrogen Dose	10	2157.77	215.78	7.95	<.001***
Error	34	1033.30	30.39		
Total	53	4367.09			

***: very highly significant (p<0.001), *: *highly significant (p<0.01), : significant (p<0.05), NS: Not significant*

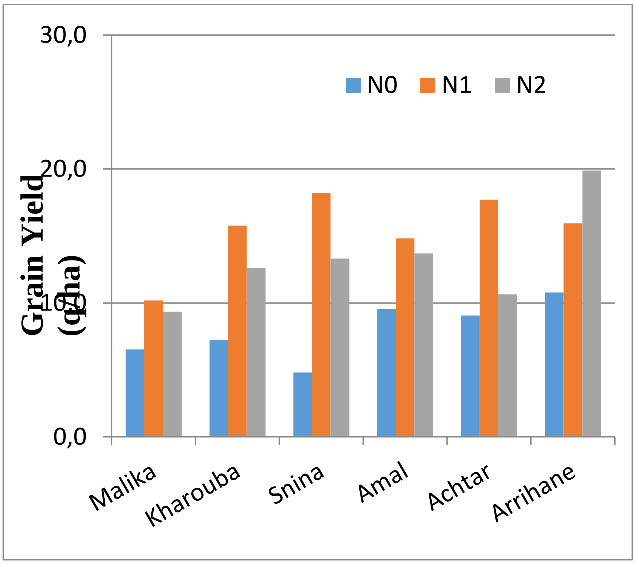

Figure 4 : Effect of Nitrogen Dose on Grain Yield in Rainfed

The results illustrated in Figure show that the N2 dose (the highest dose) yielded the highest yield across all varieties. It is also worth noting that the Achtar variety (26.8 q/ha), the Kharrouba variety (26.9 q/ha), and the Arrihane variety (28.9 q/ha) gave higher yields than other varieties under nitrogen doses N0, N1, and N2, respectively.

Yield is related to several parameters, including its components. These components are positively associated with nitrogen input, except for the thousand grain weight. Indeed, BAHLOULI et al. (2008) emphasize that achieving high yield is positively associated with the number of ears per m2, the number of grains per m2, and ear fertility.

Irrigated

- <u>Biomass</u>

The analysis of variance (ANOVA) for biomass revealed significant effects for the variety factor ($p < 0.05$), the nitrogen dose factor ($p < 0.001$), and the interaction between varieties and nitrogen dose ($p < 0.001$). Variety Arrihane recorded the highest biomass at 120.1 q/ha under N0, while Achtar registered the highest biomass under N1, and Kharrouba had the highest value (105.6 q/ha) under the N2 dose. Across all varieties, biomass remained unchanged between N0 (222.8 q/ha) and N1 (222.5 q/ha), while it increased significantly between N1 and N2 (224.5 q/ha).

Table 7: Results of the analysis of variance for biomass Irrigated

Source	***Df***	***SSE***	***Mean Square***	***F Value***	***Probability***
Block	*5*	*1744.3*	*348.9*	*3.05*	
Variety (V)	*2*	*6326.2*	*3163.1*	*27.66*	*0.022**
Nitrogen (N)	*10*	*5694.7*	*569.5*	*4.98*	*<.001****
V x N	*34*	*3887.5*	*114.3*		*<.001****
Error	*5*	*1026.19*	*205.24*	*7.56*	
Total	*53*	*4367.09*			

****: highly significant (p < 0.001), **: significant (p < 0.01), *: significant (p < 0.05), NS: Not significant*

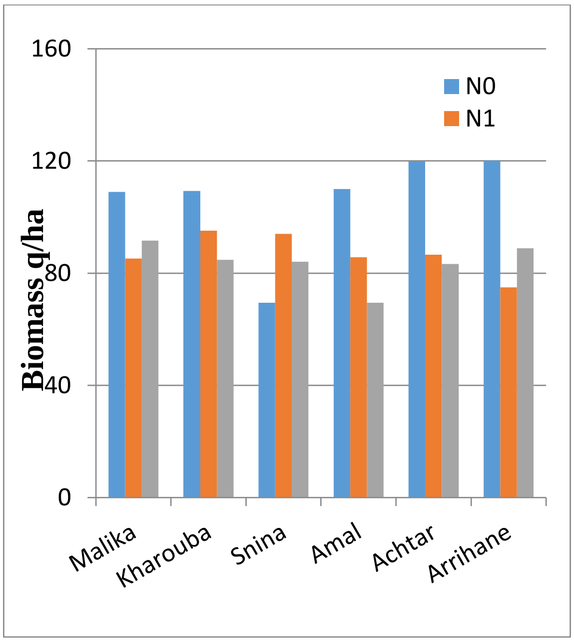

Figure 5 : Effect of Nitrogen Dose on Irrigated Biomass

The results of the nitrogen effect on the biomass of six varieties of wheat are shown in Figure 5. The analysis of these results indicates that the nitrogen dose influenced the total biomass of all varieties. It decreased with the increase in nitrogen dose. Specifically, the variety Arrihane exhibited the highest biomass (120.1 q/ha) with treatment N0, followed by the variety Achtar (119.9 q/ha), and then the variety Amal (110.0 q/ha). However, the variety Snina showed the highest biomass (94.0 q/ha) with treatment N1, and it decreased with the N2 dose (84.0 q/ha).

Grain Yield

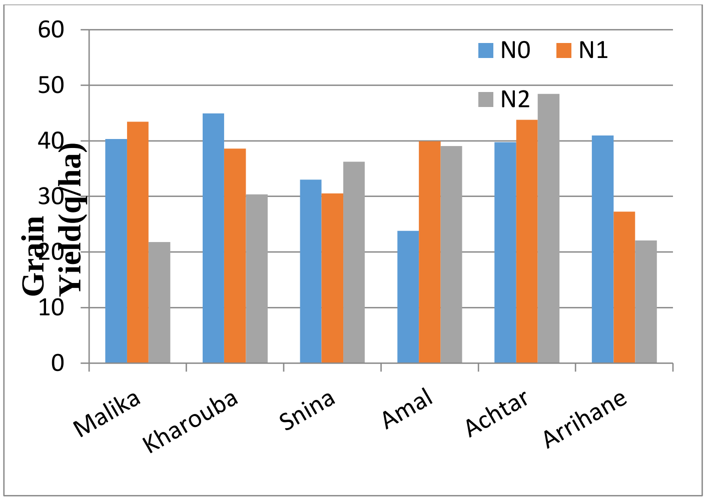

Figure 6 : Effect of Nitrogen Dose on Irrigated Yield:

The results shown in Figure 6 demonstrate the effect of nitrogen dose on the grain yield of six varieties of soft wheat. The analysis of these results reveals a significant impact of both nitrogen dose and variety on grain yield. The highest yield was recorded for the Achtar variety (48.46 q/ha) with the N2 nitrogen dose. The N1 dose yielded the highest for the Kharouba variety (44.96 q/ha) and the Arrihane variety (40.94 q/ha). Meanwhile, the N1 treatment resulted in the highest yield for the Malika and Amal varieties at 43.46 q/ha and 39.93

q/ha, respectively. Several studies have shown that increasing nitrogen dose improves grain yield (Djennadi et al., 2008; Vazquez et al., 2019).

Conclusion:

In this study, the impact of water stress and nitrogen dose on the development of tillers and the yield and its components of six Moroccan varieties of soft wheat was investigated. To achieve this objective, a field trial was conducted at the Sidi El Aidi experimental station of the INRA in Settat.

The obtained results indicate that nitrogen fertilization and irrigation influence the production of soft wheat. This effect is evident in biomass, yield, and their components. Water stress strongly influences the evolution of the number of tillers per plant, and this is influenced by nitrogen fertilization. The influence of water stress and nitrogen nutrition primarily involves slowing down the speed of tiller appearance and the competition between tillers, leading to tiller mortality. The interactions are not significant, indicating that all varieties behave in the same way in response to different nitrogen doses.

The results have demonstrated that nitrogen fertilization and irrigation are effective in improving and stabilizing yields. The nitrogen fractionation effect is significant and positive for all studied parameters. However, nitrogen dose and variety significantly affected grain yield for both water regimes. It was concluded that increasing nitrogen doses significantly improved the yield parameters of soft wheat. On the other hand, nitrogen excess can considerably reduce yield and its components, representing a higher production cost for farmers.

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