

Research paper

**Effect of supplemental irrigation, nitrogen and genotype on the bread wheat
(*Triticum aestivum* L.) productivity in Morocco**

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ABSTRACT

The objective of this study is to **determinate the optimal stage** for applying supplemental irrigation and nitrogen to enhance wheat (*Triticum aestivum* L.) productivity and water use efficiency under rainfed condition in Morocco. Field trial was conducted during two years (2007-2008 and 2008-2009). Three genotypes (G) of Moroccan bread wheat (Achtar, Arrehane and an Advanced Line II) were combined with five nitrogen rates (N) (0, 40, 80, 120 and 160 kg N/ha) and three water treatments (rainfall (I0), irrigated at tillering (I1) (60 mm) and irrigated at heading (I2) (60 mm)). During the drought year (2007-2008), results show that I2 improves water use efficiency, grain yield and its components by 91 and 60% respectively compared to I0 and I1 treatments. I2 has **deadens the harmful** effects of the Sirocco which influence this area at the end of the cycle of the crop. **During the second year 2008-2009 which was rainy, N improved grain yield and its components. The 120 kg N/ha rate have given the highest results, similar as 160 kg N/ha. No G effect was appeared recorded neither on grain yield nor on water use efficiency on both years.**

Key words: Supplemental irrigation, nitrogen, genotype, bread wheat, productivity, efficiency.

24 1. Introduction

25 Cereals are the most important crops in Morocco, it covers 5 million hectares which represent 80% of
26 arable land in the country. Unfortunately, yields are low and variable due to rainfall scarcity and
27 variability [1]. The weather forecast studies for the Mediterranean region show that these conditions
28 are likely to increase with climate change [2]. In fact, at the Saïs region of Morocco, the average
29 rainfall is passed from 600 mm per year during the period 1960-1980 to 440 mm for the period 1981-
30 2000 [3]. By 2020, the climate change scenarios in Morocco in relation with agricultural production
31 include a reduction in grain yield of cereals estimated at 50% in dry years and 10% in normal years
32 [4]. The limited availability of water is a major challenge for Moroccan agriculture through the
33 development of more efficient techniques for water. These techniques allow in one hand to increase
34 yields to fulfill need for growing population and secondly to be more efficient in the use of water as
35 the competition exerted by other non-agricultural sectors [4]. Under these conditions to increase and
36 stabilize production there has been a tendency to adopt application of high rates of fertilizer under
37 irrigated conditions [5]. Indeed, compared to non-irrigated treatment, an increase in grain yield for
38 bread wheat of 419, 389 and 281% respectively for the full supplemental irrigation (FSI), 2/3 of the
39 FSI and 1/3 of the FSI has obtained in northern Syria [6]. The effect of supplemental irrigation is more
40 marked as it is made in the early stages of crop development (early tillering) for varieties with low
41 tillering and heading stage for varieties with high coefficient of tillering. In both cases, the yield
42 increases up to 100% [7].

43 Also, nitrogen fertilization of cereals is the second factor after water, which determines the level of
44 intensification of cereal production. It is one of the most difficult practices in the dry areas. Indeed,
45 the addition of high amounts of nitrogen fertilizer in dry years and this element deficiency in wet years
46 often cause considerable falls in cereal yields [8]. Therefore, fertilizer and water should be managed in
47 order to avoid losses [9]. In the North of France, on the new variety of wheat Recital, with 170 kg
48 N/ha gave an increase of 87% of yield comparatively to control (0 kg N/ha). While the old variety
49 Cappelle is indifferent to the dose of nitrogen applied, but its efficiency is low [10].

In order to improve cereal production through the use of efficient techniques for water management and nitrogen fertilization a field trial was set up in experimental stations with the objectives (1) quantify the effects of supplemental irrigation and determine the optimum stage of its application on wheat productivity (2) check if there is a genetic variability for the efficiency of water use (3) determine the optimal intake of nitrogen for wheat in rainfed conditions and supplemental irrigation.

2. Materials and methods

2.1. Experimental site

A field trail was conducted at the Experimental Station “Douyet” (National Institute for Agricultural Research, INRA Morocco) in the province of Fez (34°2’N, 4°50’W, altitude: 416 m), for two years 2007-08 and 2008-09.

2.2. Treatments

Sowing was carried out by a drill on 26 December for the two years of the trial at a dose equal to 160 kg/ha. The three factors tested were:

- Water regime: rainfed (I0), irrigated (60 mm) at tillering stage (I2) and irrigated (60 mm) at heading stage.
- Nitrogen rate: 0, 40, 80, 120 and 160 kg N/ha.
- Genotypes: Achar (released in 1988), Arrhane (released in 1996) and an Advanced line II; not yet released).

The experiment design was a split-plot with 3 replications, the water regime in main plots while genotype and nitrogen were affected to sub-plots. The experimental area was divided into 135 plots of 5 m x 3.5 m each, with a buffer zone of 2 m between adjacent plots and 8 m between main plots. The irrigation system used is the spray.

Analysis of soil nitrogen prior to installation of the test showed that the soil was rich in this element (40 ppm NO₃⁻).

2.3 Sampling and analysis

Measures focused on the weight of the soil moisture (pre-test and post-harvest), while the total dry matter, grain yield and its components were measured at maturity (June). The calculated parameters are the soil water, harvest index and the water use efficiency for grain.

2.4 Statistical analysis

Analysis of variance was used to determine the significance ($P = 0.05$) of main effects and interactions. The S-N-K test ($P = 0.05$) was then used to compare means using ESPSS software (version 17.0).

3. Results and discussion

3.1 Weather conditions

In 2007-2008 crop year total rainfall throughout the season was 334 mm, divided into 115 mm before sowing and 219 mm during the test period. While the 2008-2009 crop year recorded 750 mm of rainfall, divided into 388 mm before sowing and 362 mm between sowing and harvest. Rainfall during the last year was well distributed throughout the crop cycle (figure 1).

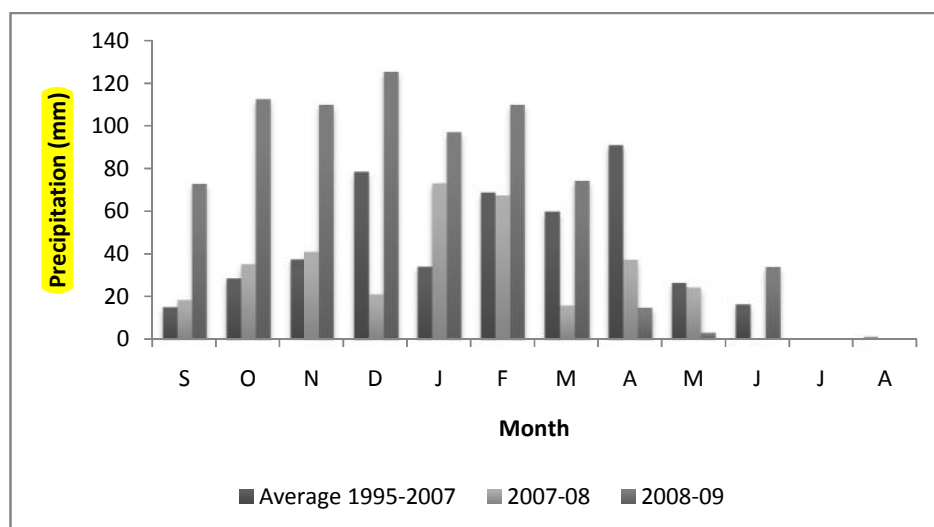


Figure 1: Distribution of rainfall in the experimental station of Douyet for 2007-2008 crop year

and 2008-2009 crop year and the average of 1995-2007

3.2 - Grain yield

The 2007-2008 crop year was a relatively dry year, the water supply had a highly significant effect on grain yield. Indeed, supplemental irrigation at tillering and heading have resulted in improvements in grain yield respectively 59.43 and 90.96% compared to rainfed (table 1). These results confirm those found in the semi-arid region of Settât (Morocco) [7, 11]. Nitrogen was not affected the grain yield. The low yields in 2007-2008 compared to the potential of the region and the effect of two drought years (2006-2007 and 2007-2008) have limited samples the nitrogen supply and we would suggest that the balance of nitrogen from previous years was sufficient to produce yields recorded. Concerning genotype, statistical analysis showed that there was no significant difference between treatments viewpoint grain yield. But, the analysis of irrigation treatments for each separately indicates a significant effect of genotype in the case of regime tillering. The LAII gave a higher yield than Achar (32.92% increase), while Arrahane does not differ from the other two genotypes. The interactions $I * N$, $G * N$ and $N * I * G * N$ did not show a significant effects.

Table 1: Effect of water regime, nitrogen rate and genotype on grain yield (qx/ha) 2007-08.

		N0	N1	N2	N3	N4	Moy G/I	Moy I	Moy G
	G1	17,69	17,78	15,99	15,99	15,10	16,51		22,41 b
	G2	17,44	17,58	16,02	17,41	17,59	17,21		23,73 b
	G3	19,60	18,06	17,15	17,80	16,84	17,89		25,0 b
I0	Moy N/I0	18,24	17,81	16,39	17,07	16,51		17,20 a	
	G1	18,79	17,84	18,96	19,59	17,48	18,53		
	G2	19,78	21,37	20,62	21,39	20,11	20,65		
	G3	22,33	23,20	25,90	26,74	25,00	24,63		
I1	Moy N/I1	20,30	20,80	21,83	22,57	20,86		21,27 b	

	G1	29,88	30,81	28,37	32,50	32,85	30,88
	G2	33,93	35,04	34,98	32,19	32,55	33,74
	G3	31,40	32,13	35,24	33,40	31,35	32,70
I2	Moy N/I2	31,74	32,66	32,86	32,70	32,25	32,44 c
	Moyenne N	23,43 b	23,76 b	23,69 b	24,11 b	23,21 b	23,64 b

Figures with the same letter (at the last line for nitrogen and two columns for irrigation and genotype) are not significantly different at 5% according to the S-N-K test.

The second year (2008-2009) was very rainy; the nitrogen had a significant effect on grain yield. Indeed, The S-N-K test, revealed the existence of three classes. The first class includes the doses 160 and 120 kg N/ha, they gave the highest yield with an average of 55.13 qx/ha, respectively, followed by class grouping doses 80 and 40 kg N/ha which recorded an average of 46.61 qx/ha and finally 0 kg N/ha gave the lowest yield with an average of 36.04 qx/ha (Table 2). The heavy rains recorded during this crop year have leached some of the nitrogen applied, which has impacted negatively on treatments that had received low doses of nitrogen. Similar results were found in France [10] and in Morocco [12]. The addition of 168 kg N/ha had no significant effect on grain yield of durum wheat (variety Karim) compared to an intake of 126 kg N/ha [12]. While, the dose 170 kg N/ha gave a yield higher than 87% compared to the doses 0 N kg/ha for wheat Recital [10]. Supplemental irrigation and genotype had no significant effect on grain yield. However, under irrigation whether heading or tillering gave an average yield of 49.38 qx/ha, higher than 5 qx/ha compared to rainfed. The interactions I * N, I * G, G * N and N * I * G * N did not show a significant effects.

Table 2: Effect of water regime, nitrogen rate and genotype on grain yield (qx/ha) during 2008-2009 crop year.

		N0	N1	N2	N3	N4	Moy G/I	Moy I	Moy G
	G1	37,16	41,55	46,96	47,42	46,45	43,92		44,69 b
	G2	41,69	47,70	49,95	52,92	53,32	49,12		49,81 b
	G3	39,73	45,32	46,84	50,21	51,35	46,69		49,38 b
I0	Moy N/I0	39,53	44,86	47,92	50,18	50,37		46,57 b	

	G1	40,05	41,37	46,17	48,54	48,84	44,99
	G2	43,23	46,72	47,34	52,05	54,46	48,76
	G3	45,28	47,34	51,39	55,43	54,69	50,83
I1	Moy N/I1	44,26	47,03	49,37	53,74	54,58	49,79 b
	G1	42,10	44,24	46,49	46,56	46,35	45,15
	G2	45,01	49,15	50,66	55,50	57,45	51,55
	G3	42,06	48,61	50,90	54,40	57,23	50,64
I2	Moy N/I2	43,06	47,33	49,35	52,15	53,68	49,11 b
	Moyenne N	42,279 a	46,41 b	48,88 b	52,03 c	52,88 c	

122 Figures with the same letter (at the last line for nitrogen and two columns for irrigation and genotype) are not significantly different at 5%
 123 according to the S-N-K test.

124 3.3 - Water use efficiency

125 The water use efficiency (WUE) for grain was influenced by water intake in 2007-08. Under irrigation
 126 at heading stage showed an efficiency of 11.89 kg/mm/ha, representing an increase of 40.3 and 49.8%
 127 respectively compared with existing irrigated at tillering and rainfed (figure 2). Similar results were
 128 observed for WUE for total biomass. Irrigation at heading has improved efficiency respectively 57.5
 129 and 43.6% compared with existing rainfed and irrigated at tillering.

130 During the rainy 2008-2009 crop year, the WUE for grain and total dry matter was influenced by the
 131 nitrogen. The S-N-K test, revealed the existence of three classes. Nitrogen dose 160 and 120 kg N/ha
 132 allow the highest WUE for grain (6.43 kg/mm/ha) higher, respectively from 41.9% to dose 0 kg N/ha
 133 and 19.5% for doses 80 and 40 kg N/ha (figure 3). These results corroborate those found in northern
 134 Syria in the case of supplemental irrigation [13]. Indeed, the dose 100 kg N/ha allowed the highest
 135 WUE for the grain (2.2 kg/mm/ha), followed by doses 150 and 50 kg N/ha (1.4 kg/mm/ha) and finally
 136 the dose 0 kg N/ha (0.7 kg/mm/ha).

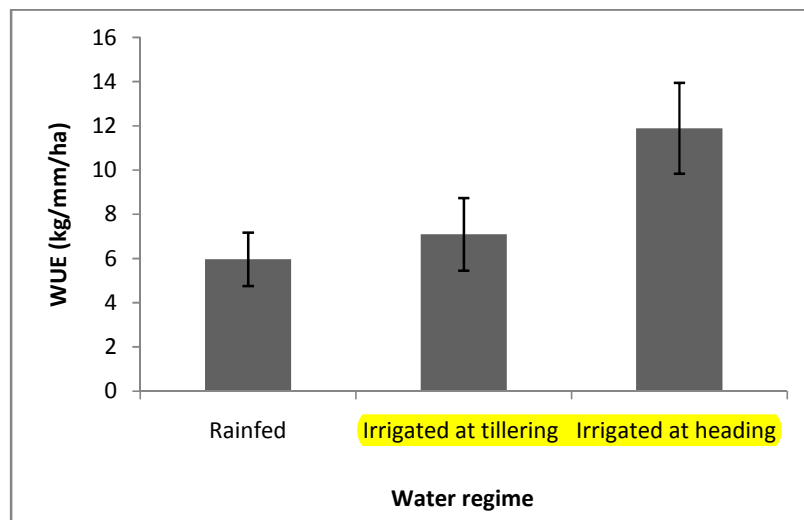


Figure 2: Effect of water regime on the WUE grain (2007-08)

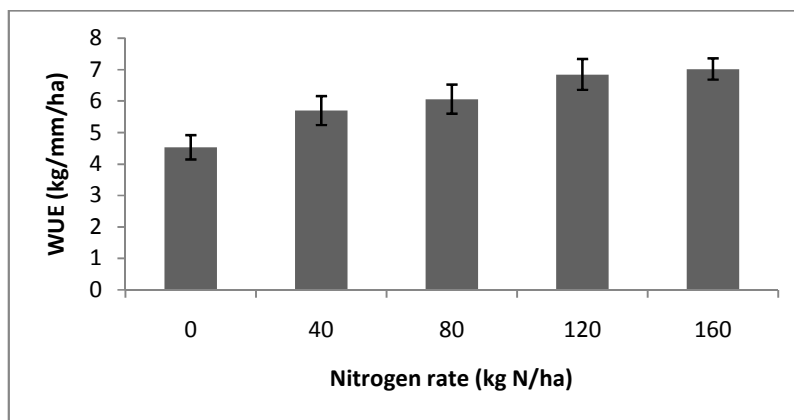


Figure 3: Effect of nitrogen rate on the WUE grain during 2008-2009 crop year

3.4 - Harvest Index

The analysis of variance in 2007-2008 crop year revealed a significant effect of water regime on harvest index. These results are similar to those obtained for grain yield. In fact, the rainfall regime gave the lowest harvest index with an average of 30.71%, followed respectively under irrigation at tillering with an average of 9.34% and under irrigation in the hearing with an average 26.12 %. Irrigation improved the grain yield and therefore the harvest index. Climatic conditions during the periods of development of the number of grains and filling them have a direct effect on harvest index.

148 Irrigation especially in the heading made at the time of cessation of rains, unlike the rainfall regime,
149 allowed the plant to convert and remobilized assimilates from the leaf to the grain.

150 During 2008-2009 crop year, the water regime has no influence on this component that the case for
151 most other components measured. But, comparing the averages of five doses of nitrogen (S-N-K test)
152 gave two classes: the first includes doses of 0, 40, 80 and 160 kg N/ha with an average of 33.91% and
153 the second includes doses 40, 80, 120 and 160 kg N/ha with an average of 36.09%. The difference in
154 performance for different rates of nitrogen was more influenced by the amount of dry matter produced
155 rather than the translocation of assimilates to the grain as was the case for the dry year.

156 3.5 - Grain Weight

157 The thousand grain weight in 2007-2008 crop year was influenced by the water regime. The highest
158 weight (36.14 g/1000 grains) was obtained with irrigation at heading, while the other two diets showed
159 values statistically equal (26.26 g/1000 grains). Even under irrigation in the heading did not express
160 the highest potential weight of 1000 grains. However, irrigation at this stage helped cushion the
161 negative effect of hot winds (Sirocco) that prevalent in the region at the end of the crop cycle. For
162 genotype and nitrogen dose, the effect was not significant on this component.

163 In 2008-2009 crop year (wet year), nitrogen had the most significant effect on this parameter. The
164 dose 0 kg N/ha gave the lowest weight of 1000 grains with an average of 32.41g, followed by the
165 other doses which have the similar effect with an average of 36.84g/1000 grains. In contrast, in France
166 for fifteen wheat genotypes tested an average weight of 1000 grains equal to 43.1g for dose 0 kg N/ha
167 was obtained and 40.9 g for dose 170 kg N/ha. Unlike the 1000 grains weight genotypes VM014,
168 Audacity, the variety Etoile de Choisy, Sidereal and Camp Rémy are indifferent to the dose of
169 nitrogen applied [10]. For the water regime, although the S-N-K test, revealed the existence of two
170 classes: the first includes systems rainfed and irrigated at tillering with an average of 35.34g and the
171 second contains the two regimes irrigated (tillering and heading) with an average of 36.83g. This
172 difference was not very significant to influence the final grain yield. Genotype and the different
173 interactions had no effect on this component.

174 3.6 - Number of grains per unit area

175 Water regime had a highly significant effect in 2007-2008 crop year on the number of grains per unit
176 area. The ranking shows that averages the highest number was recorded for water supply at heading
177 (9047 grains/m^2), followed by water supply at tillering (7837 grains/m^2) and late rainfall regime (6447
178 grains/m^2). In general, the number of grains per unit area was determined by the population spike only,

179 rather than the other components of the year that have not recorded any significant differences. This
180 result confirms those found in the semi-arid region of Settat (Morocco) [11].

181 This component performance has been greatly influenced in 2008-09 by the nitrogen. The S-N-K test
182 revealed the existence of three classes. The first includes doses of 0, 40 and 80 kg N/ha, who gave the
183 lowest number of the grain (12408 grains/m^2), followed by doses of 40, 80 and 120 kg N/ha with an
184 average (13488 grains/m^2) and the doses 80, 120 and 160 kg N/ha with an average of (14469
185 grains/m^2).

186 Although genotype had no effect on most components measured, it is thanks to the component number
187 of grain per unit area than the variety Arrehane could achieve a similar grain yield to other genotypes
188 although it has been penalized for all yield components measured in the dry year.

189 Conclusion

190 Water regime greatly influences the production of bread wheat in the Saïs region, especially in dry
191 years. Irrigation at heading with 60 mm could double production from the rainfed (91% higher). But in
192 rainy year as was the case of the 2008-2009 crop year, supplementary irrigation does not allow
193 significant gains in production. However, supplemental irrigation (at tillering or at heading) might
194 result in an additional 5 qx/ha of yield compared to rainfed, which is not negligible given the
195 difference between the cost of an irrigation of 60 mm and the price of 5 qx/ha.

196 In drought conditions and when the soil is rich in nitrogen, the residual soil nitrogen provided by the
197 previous crop may be sufficient to ensure an average production of bread wheat (34 qx/ha). But in

198 conditions where water is not limiting and even if the soil is rich in nitrogen, 120 kg N/ha gave the
199 highest yield.

200 There were no significant differences for the total yield between the genotypes in two contrasting
201 years. However, the variety Arrehane was penalized for almost all measured yield components; but the
202 increase of one yield component – the number of grains per unit area- explains the maintain of total
203 yield. Olso, the different interactions did not influence the different components measured

204 **Acknowledgements**

205 We thank Ms. Khalfi C.D and Mr. Taybi A. and all the staff of Douyet Experimental Station for their
206 assistance during the installation and testing of different measurements. Also, I would like to thank Dr.
207 Hadarbach D. for his help in the statistical analyzes.

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