IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 12 Ser. I (December 2020), PP 01-06
www.iosrjournals.org

Effect of nitrogen and water supplies on durum wheat (*Triticum turgidum var*. durum) response under semi-arid environment

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Abstract:
Background*: Water and nitrogen (N) are the important compounds in plant production and its deficit is a growth limiting factor.*
Materials and Methods*: A field trial was conducted to evaluate the effect of three nitrogen fertilization applied at different rates (0, 100 and 200 kg N/ha) of three wheat (Triticum turgidum var. durum) cultivars (Maali, Selim and Nasr) under the same cropping practices (sowing date, seeding rate, row space and seeding depth). Durum wheat response was assessed under supplemental irrigation and rainfed conditions. Plant number/m² (PN), tillers number/plant (NT), spike number/m² (SN), kernel number/spike (KN), thousand kernel weight (TKW), fresh weight shoot (FWS), dry weight shoot (DWS) and height plant (HP) were studied.*
Results*: Variance analysis showed that all traits were significantly (P<0.01) influence by N fertilization expect NT in general for most cultivars. A signifiant increase in nitrogen application rate had resulted in an increase of component of yield. The optimum yield was produced for all cultivars at 200 kg N/ha rate. Results showed that cultivar Maali and Selim were more affected by nitrogen fertilization than cultivar Nasr. Selim variety showed the important TKW, KN and SP for all N regimes. Regardless of cultivar, results showed that supplemental irrigation significantly increased PN, SN, FWS and TKW with respect to the rained treatment. Maali and Selim were less affected by supplemental irrigation than Nasr.*
Conclusion: *Combined the two factor (Nitrogen and water supply), the optimum yield was produced for all cultivars at supplemental irrigation and nitrogen rate of 200 kg N/ha and the Selim variety had the most performing one. Thus, this variety could be recommended for semi-arid region as Siliana site.*
Key Word*: durum wheat, nitrogen fertilization, semi-arid environment, supplementary irrigation*
Abbreviations: *N: nitrogen; PN: Plant number/m²; TN: tillers number/plant; SN: spike number/m²: KN: kernel number/spike; TKW: thousand kernel weight; FWS: fresh weight shoot; DWS: dry weight shoot and PH: plant height.*

Date of Submission: 25-11-2020 Date of Acceptance: 09-12-2020

I. Introduction

Durum wheat (*Triticum turgidum* var. *durum*) is an important cereal crop grown in many parts of the world. Nitrogen nutrition is considered as the second most limiting factor for durum wheat yield loss in non-fertilized agriculture of the Mediterranean environment (Borghi et al., 1997; Alam et al., 2007). All crops need nitrogen (N) to product a photosynthetically active canopy, whose functionality will powerfully influence yield (Hawkesford, 2014). Nitrogen is non-substitutional resources required for microbial growth (Hodge et al., 2020). As reported by Lian-peng et al., (2012), in winter wheat systems, nitrogen is one of the mainly limiting nutrients for grain yield; therefore applied N fertilizer will obviously drive productivity. It is a crucial input factor needed for biomass production and plant growth (Murozuka et al., 2014; Mosanaei et al., 2019). Also, Kamiji et al. (2014) reported that an average of 30% to 50% of the nitrogen applied as fertilizer is taken up by wheat. The choice of genotype and nitrogen fertilization rate is one of the recognized cultivation techniques that have an important influence on grain yield and its components (Boukef et al., 2013; Khan et al., 2020).

Crop responses to N fertilization depend on soil water availability, rainfall amount and distribution during the crop cycle, further than amount and timing of N applications (Pala et al., 1996; Latiri-Souki et al., 1998). The biggest provider to variation in crop and plant performance in wheat was ‘N-rate’ followed by ‘growth stage’ then ‘genotype’ (Barraclough et al., 2014). Rising N supply to a crop aims to the production of a superior biomass with the potential for a high photosynthesis and productivity (Hawkesford, 2014). Ali et al. (2011) reported that N fertilizer is known to have an effect on the number of tillers m^{-2}, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, spike length and 1000 grain weight. It is largely proved that the early developmental processes, such as tiller proliferation, occurring during early growth, depend on the availability of water and N in durum wheat (Simane et al., 1993).Under Mediterranean conditions, yields of cereal are low and inconsistent in response to inadequate and irregular seasonal rainfall (López –Bellido and López –Bellido, 2001). In most semi-arid regions in the world, the lack of rainfall limits the growth of wheat. Therefore, controlled irrigation and soil fertilization are vital for increasing crop yields (Recio et al., 1999; Li et al., 2001). In fact, better understanding the effects of N and water on grain yield and quality; it can be possible to optimize annual irrigation and N management (Kharel et al., 2011). Availability of N has effects throughout crop development, touching seedling establishment, tillering, canopy growth as well as grain filling, so they have the potential to influence yield and together find out the N necessities of the crop (Hawkesford, 2014). Therefore, combined water and N shortages at anthesis stage induce flower abortion resulting in a reduced grain number (Jeuffroy and Bouchard, 1999; Acevedo et al., 2002). Thus, the understanding of the interactive effects of water and N availability, along with the crop ability to efficiently use these resources (expressed by water and nitrogen use efficiency, respectively) is of crucial importance for stabilizing the cereal production in the Mediterranean areas. Water deficit during the growth period (from double ridge to anthesis) and around anthesis causes yield losses due to reductions in potential grain number per unit land area (Savin and Slafer, 1991; Giunta et al., 1993; Cossani et al., 2009) while drought stress and high temperatures during grain filling period, as it often occurs in Mediterranean conditions, reduce mean kernel weight (Oweis et al., 2000; Acevedo et al., 2002). Diverse lines of evidence reveal that irrigation level is strongly associated with plant nitrogen uptake (Guo et al., 2014). Informations on yield and yield related traits under different nitrogen in rainfed or irrigated conditions rates for most of the recently released are limited. Thus, in this work the effects of nitrogen application rates on component grain yield was studied for three durum wheat varieties under rainfed and irrigated conditions.

II. Material And Methods

This field study was conducted to evaluate the effect of N fertilizer and water supply irrigation stress on durum wheat during 2012/2013 cropping season in a randomized split plot design with three replicates in a semi-arid region Elgantra (Siliana) at Lakhmes research station. The Siliana region is located in the North-Ouest of Tunisia at 39°, 39' N latitude and 47°, 49' E longitude, and at an altitude of 50m.a.s.l with annual rainfall ranging between 300 and 450 mm and an annual average temperature of 14.6°C.

Nitrogen treatments were fertilized with ammonitrate. The HN (high nitrogen) treatment with a total of 200 kg /ha of N applied, is applied respectively before sowing (100 kg/ha) and the beginning of tillering stage (100 kg/ha). The LN (low nitrogen) were fertilized at heading stage (100 kg/ha). Control treatments were unfertilized, relying exclusively on the N availability in the soil before sowing. The experiment field received 100 kg/ha of Di-Ammonium Phosphate at sowing. In this study, plant density was 160 kg/ha for durum wheat. Plots were sown on 24 December 2012 using a template to produce 10 rows of plants 12 cm apart.

Water treatments were designated as rainfed and supplemental irrigation (SI), with the SI treatment supplemented by sprinkler irrigation distributed in tow similar amounts (25 mm) at the head emergence and irrigation at the flowering stage respectively. In addition and due to the lack of late autumn rainfall the 2012/2013 received of 130 mm supplementary water to ensure plant emergence.

According to soil analysis carried out prior to sowing, the soil texture was a clay-loam with potassium=458.7 ppm, phosphorus=19.42 ppm, sand (%) = 15, O.M (%) = 1.72, soil P_2O_5 = 19.4 ppm, K_2O =458.7 ppm, N = 69.53 ppm, $CaCO_3$ (%) = 64.9 and pH =7.9. Climate temperature and rainfall from sowing to harvest are presented in Table 1.

Table 1: Mean temperature (°C) and rainfall (mm) of El Gantra-Siliana site from sowing to harvest (2012 to 2013)

Months	October	November	December	January	February	March	April
Rainfall (mm)	112.4	28.4	9.2	35.6	28.6	42.7	36.9
Temperature (°C)	26.8	21.8	16.2	15.1	13.9	20.5	23.6

Plant number/m², tillers number/plant, spike number/m², kernel number/spike, 1000 kernel weight, fresh weight shoot, dry weight shoot, plant height and 1000 kernel weight were studied.
The analysis of variance (ANOVA) for each character was performed followed by Duncan's test to reveal the significance difference between means. The data were statistically analyzed by SPSS software.

III. Results and discussion

Water and nitrogen regimes and variety were evaluated. Analysis of variance is presented in Table 2. Water and nitrogen regimes and genotype had significant effects on almost traits measured (Table 2). These results corroborate those of Wang et al. (2014) in which irrigation and nitrogen application influence NS and TKW. According to the variance table, plant number m^{-2}, tillers number m^{-2}, ear number m^{-2}, fresh weight shoot and 1000 kernel weight was affected significantly by water stress except dry weight shoot, plant height, kernel number $spike^{-1}$. TKW under irrigated treatment exceed significantly those registered under rainfed conditions. Similar effects of water stress on TWK were also obtained by Akram (2011). According Khan et al. (2020), deficit irrigation resulted in lowest number of grains per spike, tiller per unit area, spike number per spike, 1000-grain weight, and biological yield of wheat crop.

Table 2: Analysis of variance (value F) of all traits measured of the 3 durum wheat varieties for the 2 water regimes and 3 Nitrogen regimes

Variance Sources	df	PN	SN	FWS	DWS	HP	TN	TKW	KN
Variety	2	11.22**	16.83**	3.28*	1.24ns	3.14*	9.52***	5.9 ***	11.03***
Water regime	1	21.88***	16.73***	6.36*	0.18ns	0.262ns	11.7**	393.74***	1.55ns
N regime	2	20.96***	32.66***	13.53***	19.46ns	17.54***	5.02**	142.76***	25.22***
Variety x N regime	4	3.19*	6.88***	0.34ns	0.50ns	1.00ns	0.13ns	2.32ns	1.19ns
Variety x water regime	2	0.74ns	2.56ns	2.69ns	3.24ns	0.01ns	0.11ns	27.53**	1.53ns
N regime x water regime	2	0.71ns	0.32ns	0.66ns	0.21ns	0.31ns	0.20ns	9.63**	0.56ns
Variety x N regime x water regime	4	0.02ns	0.80ns	0.24ns	0.51ns	0.06ns	0.07ns	3.20**	0.45ns

Significant at $P = 0.05$* or at $P = 0.05$** (F-test).
PN: Plant number/m², SN: spike number/m², FWS: fresh weight shoot, DWS: dry weight shoot, HP: height plant, TN: tillers number/plant, KN: kernel number/spike, TKW: thousand kernel weight

In the present study, there were also significant differences between the three durum wheat varieties for all parameters measured, except dry weight shoot. All traits were influenced by N fertilization. Nitrogen is believed to be an efficient up-regulatory nutrient for plants grown under stress and also non-stress conditions (Jiang et al., 2008; Mosanaei et al., 2019). The effect of nitrogen fertilization rates on durum wheat varieties and parameters are given in Table 3.

The optimum nitrogen rate to improve agronomical traits and components yield potential are 100 and 200 kg/ha. Nitrogen application had positive influence on all the yield components for the tested durum wheat genotypes. These results are in agreement with those achieved by Ali et al. (2011) and Hussain et al. (2006). The NT, HP, KN and TWN were significantly increased by augmenting the nitrogen levels over control treatment. Same finding are obtained by Weisz *et al.* (2007) and Hussain *et al.* (2006) in bread wheat, where different nitrogen levels had significant effects on HP, KN and SN. However, Fallahi *et al*. (2008) showed that increasing nitrogen from 60 to 90 Kg N/ha did not increase agronomical traits. In fact, wheat showed no yield increase above 100 kg/ha (López-Bellido *et al.* 2001). According to Oad *et al.* (2004), the application of 120 Kg N/ha of N fertilizers resulting in greater wheat yield and yield components. The cultivars Selim and Maali showed better grain yield performance than Nasr at the highest rate of nitrogen (200 kg) probably due to the highest response by these cultivars to N and use efficiency. The component yield variation among durum wheat varieties under different nitrogen levels could help in the selection of better variety for different N supply environments and similar results of cultivars variations in durum wheat grain yield on nitrogen applications were also reported (Metwally et al., 1998). For all traits, except for TKW, there was no significant interaction between N and water regime (table 2) and it is similar to Kharel et al. (2011) results where, for the measured characteristics, water × N treatments interactions were not significant.

Table 3: Mean of all traits measured of the 3 durum wheat varieties for the 2 water regimes and 3 Nitrogen regimes used

	PN	SN	FWS	DWS	HP	TN	TKW	KN
				Water Regime				
Irrigated	325.48b	306.87b[1)]	9.37b	3.11a	78.83 a	2.58 a	46.48a	38.48a
Rainfed	285.17a	275.52a	8.48a	3.22a	80.60 a	2.17 a	37.22b	38.36a
				Nitrogen Regime				
N0	278.89a	264.89a	8.14a	2.91a	70.67a	2.33a	37.90a	33.17a
N1	315.89b	302.89 b	7.72a	2.86a	81.56 b	2.33a	43.23b	38.50b
N2	330.17b	312.78b	11.11b	3.70b	86.56 b	2.56a	46.67b	41.89c
				Genotypes				
Nasr	333.78a	316.89a	7.61a	3.01a	74.72 a	2.11a	40.87a	39.92a
Maali	286.39b	274.67b	9.99a	3.46a	82.17 b	3.00 b	41.39a	46.46b
Selim	304.78b	289.00b	9.39a	3.00a	81.89 b	2.11a	45.21b	51.03c

PN: Plant number/m², SN: spike number/m², FWS: fresh weight shoot, DWS: dry weight shoot, HP: height plant, TN: tillers number/plant, KN: kernel number/spike, TKW: thousand kernel weight

[1)]:Means with similar letter(s) in each trait is not significantly different at 5% probability level according to Duncan's multiple range test

Regardless of cultivar, results showed that supplemental irrigation significantly increased plant number/m², spike number/m², fresh weight shoot and 1000 kernel weight with respect to the rained treatment, while nitrogen fertilization was observed to have significant effects on all traits measured. Moreover, results showed that grain yield for cultivar Maali and Selim were less affected by supplemental irrigation and more affected by nitrogen fertilization than cultivar Nasr (figure 1). However, cultivar effects were lower magnitude compared with those of irrigation and nitrogen. We conclude that optimum yield was produced for all cultivars at supplemental irrigation and N_2 rate of 200 kg N/ha. According to Zhou et al (2020), 98 % of maximum yield occurred when the N application rate was 185 kg/ha on field experiments in the North China.

According the table 3, irrigation water supply influenced TKW more than grain number per spike, contrary to the results obtained by Garcı´a del Moral et al. (2003) and Karam et al. (2009) for winter cereals in semi-arid environments. These results can be explained by the non limited water availability conditions occurred during the most sensitive stages to drought stress for winter cereals with respect to grain yield, i.e. the early growth period and from double ridge to anthesis (Shpiler and Blum, 1991). Stages of flowering and grain- filling are recognized as among the mainly critical stages of wheat growth and development to water deficit, during which wheat shows the highest sensitivity to water stress (Shamsi et al., 2011). According several studies, Mediterranean conditions water deficit from anthesis to maturity (especially during grain filling period) causes yield losses due to reductions of grain number per square meter and mean kernel weight (Acevedo et al., 2002).

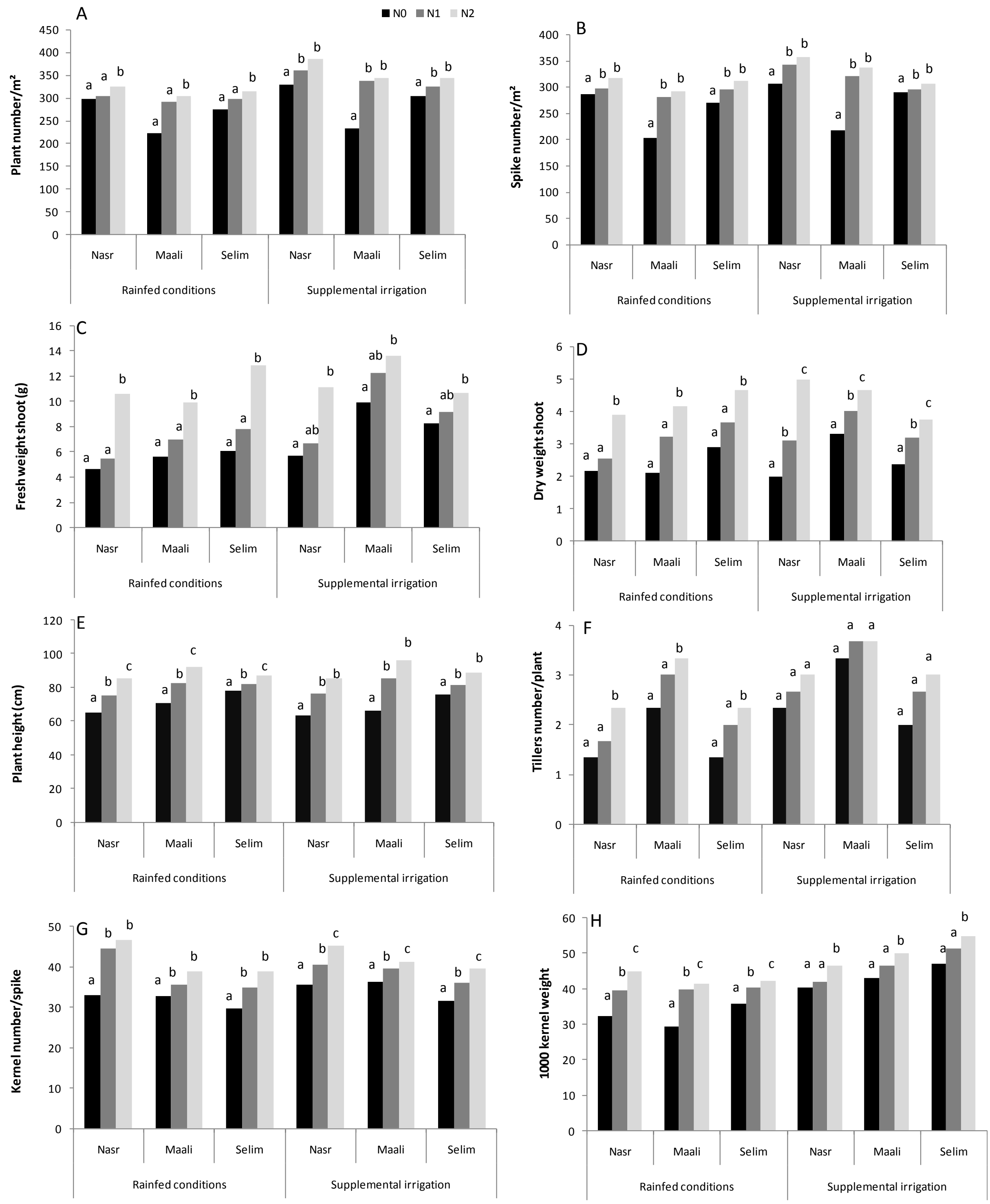

Figure 1: Plant number/m² (A), spike number/m² (B), fresh weight shoot (C), dry weight shoot (D), plant height (E), tillers number/plant (F), kernel number/spike (G) and 1000 kernel weight (H) respectively in rainfed and supplemental irrigation conditions

IV. Conclusion

For nitrogen and water supply, the best yield was obtained using supplemental irrigation and nitrogen rate of 200 kg N/ha. Selim variety had the most performing one. Thus, this variety could be recommended for semi-arid environment.

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