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Yield of Durum Wheat Cultivar Grown under Different Nitrogen Regimes and Rainfed Conditions

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Abstract: The experiment was conducted in randomized complete block design with three replications in two different locations (Kef and Bousselem). The effect of four nitrogen treatments (0, 75, 100, 120 and 140 kg/ha of N) was assessed for Maali durum wheat variety on five agronomic traits: biological yield, grain yield, harvest index, 1000 kernel weight and nitrogen use efficiency. Analysis of variance revealed significant effect (P< 0.01; P< 0.001) of the nitrogen treatments for all studied traits. However, no nitrogen treatment x site interaction was noted. Except for nitrogen use efficiency, both location exhibited significant variation (p<0.01) for all the traits examined. Biological yield, grain yield, harvest index, 1000 kernel weight and nitrogen use efficiency increased with an increase in nitrogen levels. In comparison to kef site, greatest results were obtained in Bousselem site under all nitrogen levels for all measured traits. Maximum average yield (2157.27 kg/ha) and (3013.11 kg /ha) was unregistered under N4 treatment (140 kg/ha) in Kef and Boussalem site respectively. A significant and positive correlation was noted between nitrogen rates and biological yield (r = 0.74**), grain yield (r = 0.66**), harvest index (r = 0.84**) and 1000 kernel weight (r = 0.85**). In this region, it seems that the application of 140 kg/ha of N fertilization lead to great agronomic performance of Maali durum wheat variety.

Key words: nitrogen, site, yield, nitrogen use efficiency.

Background

Cereals monocultures reduce yields and deplete soil nitrogen. It may be improved by different tools such as nitrogen fertilization (Abera et al., 2015). Cossani et al. (2012) reported that nitrogen shortages can be crucial in defining grain yield under rainfed conditions. In fact, nitrogen is the major limiting nutriment of durum wheat production because it affects plant growth, development and also grain yield. New variety need an improvement of their technological package, within N supply is highlighted (Hirzel et al., 2010). In Tunisia, farm experimentation showed in durum wheat a positive yield response to N (Cossani et al., 2011). Several reports showed that N application increased significantly grain yield of wheat, number of fertile tiller per unit area, number of grain per spike and harvest index (Asif et al., 2012; Mandic et al., 2015). Dencic et al. (2011) and Flores et al. (2012) recorded increased grain yield and its components with increase in nitrogen level. Nitrogen influenced the different growth stages of wheat by increasing leaf area, tillering, plant high, ear number per unit area, number of grains per spike, 1000 grain weight and this increasing caused high production of dry matter and grain yield (Ryan et al., 2009; Singh et al. 2000; Jamaati-e-Somarin et al., 2010). Silvina et al. (2005) reported that the application of N fertilizer in wheat affected the biomass. The biomass is ultimately related to the processes of photosynthesis and respiration during the vegetative and reproductive stages (Demétrio et al., 2012). The determination of the harvest index (grain yield/biological yield) is an indicator for defining the rate with which photo assimilates are transported to straw and grains (Silva et al., 2012). Demétrio et al. (2008) and Silva et al. (2015) reported that this parameter is influenced by cultivars, water and nutrients, soil type and climatic conditions. Thus, N management improves nitrogen use efficiency (NUE) by adjustment of N fertilizer applications to each site-specific conditions to abate N losses and improve crop performance (Dawson et al., 2008). Rahimizadeh et al. (2010) reported that NUE for

cereal production including wheat is approximately 33% in the world and it can be influenced by crop species, soil type, N fertilizer dose and rotation system. Therefore, this aims to determine the suitable dose of nitrogen for better growth and higher yield of Maâli durum wheat under two different weather conditions.

Material and methods

Vegetal Material

Maâli durum wheat variety was conducted in RCBD experimental design in 2 sites: Higher Agriculture School of Kef, located in the North Ouest of Tunisia (Altitude of 780 m) and in National Institute of Cereal station in Boussalem. Total annual rain precipitation on growing season was 319 mm and was 541 mm (mean) for the long-term in kef and Bousselem site respectively (figure 1).

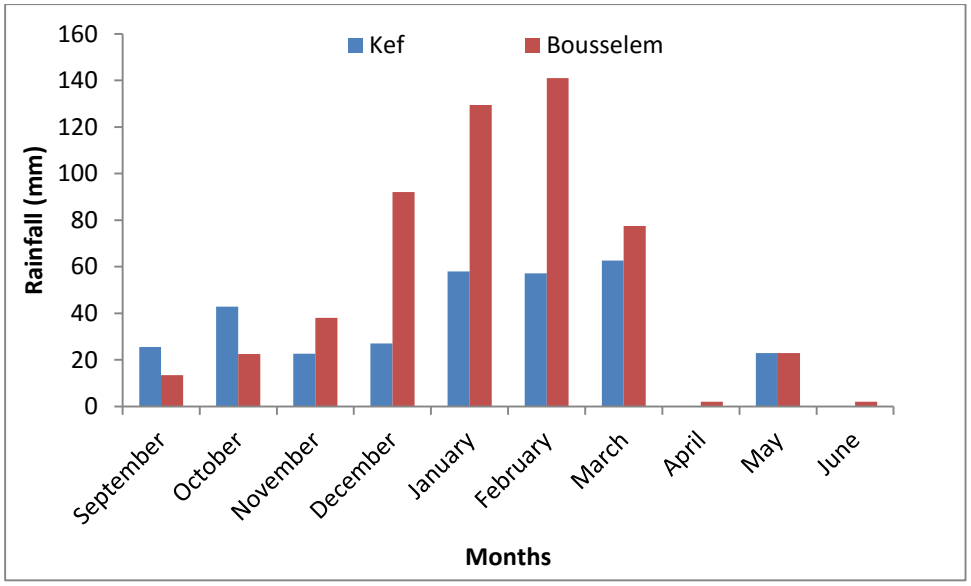


Figure 1: Monthly rainfall distribution in kef and Bousselem sites during 2014-2015 growing season.

Trial design

The experiment was designed in randomized complete block design with three replications comprising four nitrogen treatments. Each plot had 6 rows, 5 m in length

and 20 cm between rows, forming the experimental unit of 5 m^2. Plots were sown 24 December in with a seeding rates of 160 kg/ha. An herbicide Puma evolution (Bayer SAS Division Crop Science - 16, rue Jean-Marie Le clair - CS 90106 - 69266 Lyon Cedex 09 France) was applied at the dose of 1 l/ha as treatment for weed control.

Nitrogen application: Four concentrations of nitrogen were applied. N0: 0 kg/ha ; N1: 75 kg/ha; N2:100 kg/ha; N3: 120 kg/ha; N4: 140 kg/ha

Measured traits

In order to evaluate the effect of nitrogen treatment in the 02 locations, four parameters were measured: biological yield (BY) and grain yield (GY) which were hand harvested from each plot at maturity stage then (determined and recalculated to Kg per ha), harvest index (according to GY/BY equation) and 1000 kernel weight. Nitrogen use efficiency (NUE) is calculated by following equation:

NUE = (Grain $yield_F$ – Grain $yield_C$) / Fertilizer N applied kg kg^{-1} (Craswell and Godwin, 1984)

Grain $yield_F$: grain yield under fertilized condition; Grain $yield_C$: grain yield under fertilized condition control

Data analysis

All data were statistically analyzed by ANOVA using SPSS software 16.0. Mean separation was performed only when the F-test indicated significant ($P<0.01$; $P<0.05$) differences among the factors. The different interactions were also reported and significant differences were analyzed at $P<0.05$.

Results

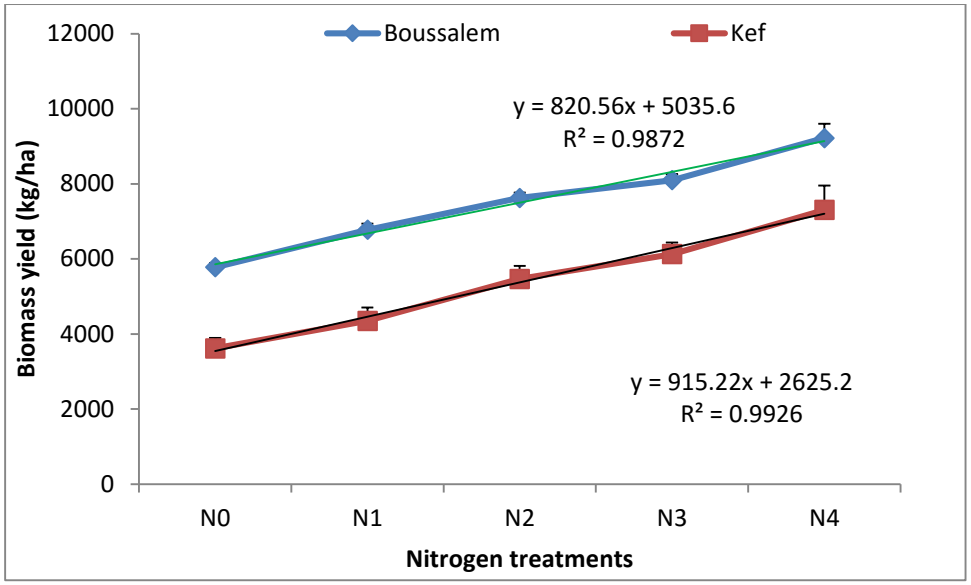
Biological yield, grain yield, harvest index and 1000 kernel weight analysis of variance are presented in Table 1. All traits were significantly ($P<0.01$; $P<0.001$) affected by nitrogen treatments. Except for NUE variance analysis revealed significant ($P< 0.05$; $P< 0.01$) effect of site. However, no nitrogen treatment x site interaction was noted.

Table 1: Analysis of variance (F test) for biological yield, grain yield harvest index and 1000 kernel weight of Maali durum wheat variety for 04 nitrogen levels

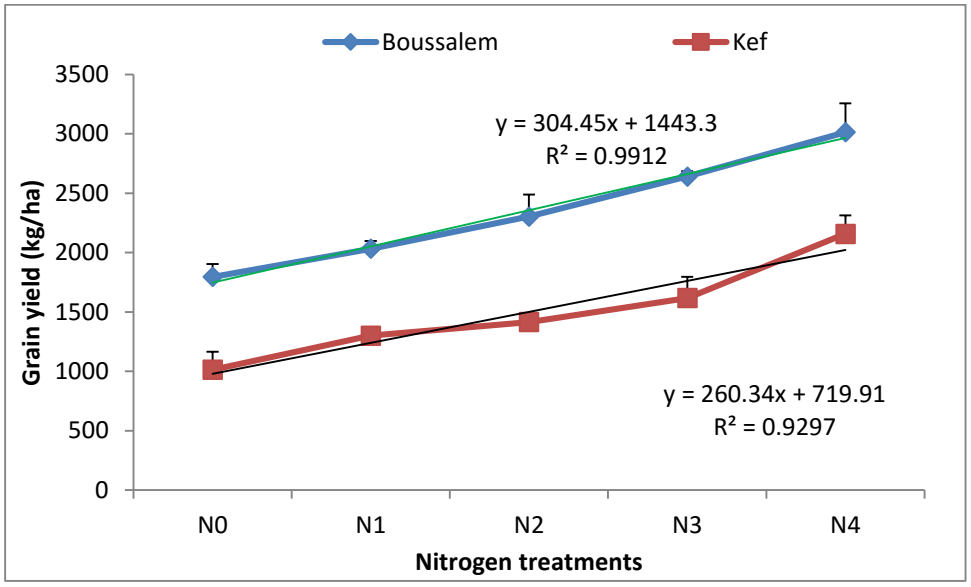
Variation sources	Biological yield (kg/ha)	Grain yield (kg/ha)	Harvest index (%)	1000 kernel weight (g)	Nitrogen use efficiency kg kg^{-1}
Nitrogen treatment	106.51**	62.88**	38,13**	31.47**	32.01***
Site	317.26**	280.93**	29.13*	12.46**	3.76 ns
Nitrogen treatment x Site	0,56ns	0,96ns	2,84ns	0,87 ns	2.19 ns
R^2	0.96	0.94	0.86	0.82	0.86

ns: not significant; * F test significant at (P>0.05) level; **: F test significant at (P< 0.01) level; ***: F test significant at (P< 0.01) level.

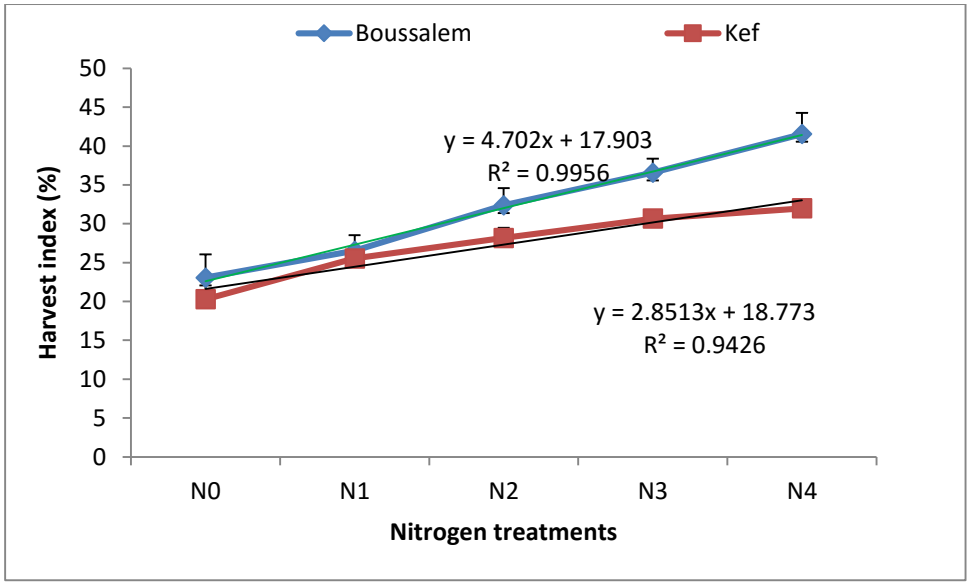
For all nitrogen levels Boussalem site showed the best results for all traits measured compared to kef site. Maximum average yield was obtained at 2157.27 kg/ha and 3013.11 kg /ha for N4 in Kef and Boussalem sites respectively (Figure1). This superiority could be explained by differences between sites in weather conditions in particularity the amount of rain which is 319 mm in kef and 541 mm in Bousselem from September to June. Biological yield, grain yield, harvest index and 1000 kernel weight increased with an increase of nitrogen levels (Figure 2A-D). Maximum grain yield was correlated with the highest level of nitrogen fertilization (r=0.95**).


Boussalem
Kef
y = 820.56x + 5035.6
R² = 0.9872
y = 915.22x + 2625.2
R² = 0.9926
Biomass yield (kg/ha)
12000
10000
8000
6000
4000
2000
0
N0
N1
N2
N3
N4
Nitrogen treatments

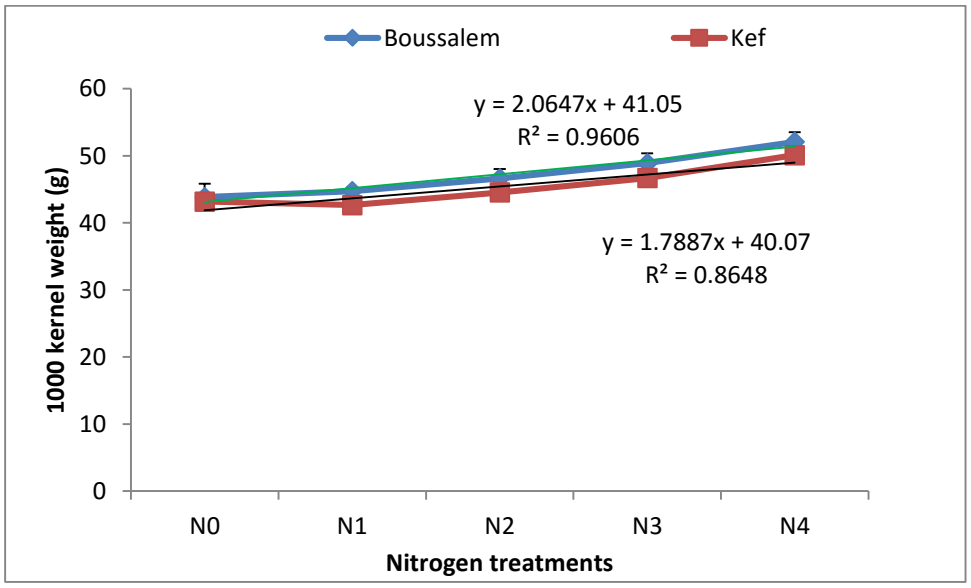
(A)


Boussalem
Kef
y = 304.45x + 1443.3
R² = 0.9912
y = 260.34x + 719.91
R² = 0.9297
Grain yield (kg/ha)
3500
3000
2500
2000
1500
1000
500
0
N0
N1
N2
N3
N4
Nitrogen treatments

(B)



(C)



(D)

Figure 2: Biological yield (A), Grain yield (B), Harvest index (C) and 1000 kernel weight (D) of Maali durum wheat under different nitrogen rates

Nitrogen fertilization at all rates improved grain and biomass yields compared to the unfertilized treatment. NUE increase with the increase of nitrogen dose supplied in each site. It varied from 3.16 and 3.83 kg kg^{-1} at N_{75} to 8.70 kg kg^{-1} and 8.17 kg kg^{-1} at N_{140} in Bousselem and Kef respectively (Table 2).

Table 2: Effect of mineral N fertilization on grain yield (kg/ha) and N use efficiency (kg yield per kg of N applied) of Maali durum wheat variety

N fertilization levels	Grain yield (kg/ha)		NUE kg kg^{-1}	
	Boussalem	Kef	Boussalem	Kef
N_0	1794.84	1013.45	-	-
N_{75}	2032.30	1301.42	3.16	3.83
N_{100}	2302.90	1415.36	5.08	4.01
N_{120}	2640.25	1617.2	7.04	5.03
N_{140}	3013.11	2157.27	8.70	8.17

Different agronomic traits were significantly and positively correlated to N fertilization: biological yield (r = 0.74), grain yield (r = 0.66), harvest index (r = 0.84) and 1000 kernel weight (r = 0.85).

Discussion

Globally, nitrogen is considered as the principal limiting factor in the durum wheat production and grain yield. Nitrogen application had positive influence on all traits. The increase of biological yield, grain, yield harvest index and 1000 kernel weight showed an exponential trend for the tested durum wheat genotype. Similar results were reported by Gashaw et al. (2013) and founded by to Hirzel et al. (2010) for grain yield and to Shah et al. (2011) for biomass yield in wheat cultivars. Biological yield increase is the result of N fertilization effect on vegetative growth of wheat which is related to the increase in tillers number with higher nitrogen rates (Shah et al. 2011). In both sites, Highest values of biological yield (9219.44 and 7302.77 kg/ha), grain yield (3013.11 and 2127.57 kg/ha), 1000 kernel weight (52.08 and 50.11 g) were unregistered under N4 treatment (140 kg N ha^{-1}) in Bousselem and Kef sites respectively. However, Shah et al. (2011) found that greatest values 1000-grain weight (42.19 g), grain yield (4145.14 kg ha^{-1}), biological yield (10579.75 kg ha^{-1}), were noted from the plots fertilized with 120 kg N ha^{-1} for wheat cultivars. Moreover, supply of 150 and 200 kg N ha^{-1} did not induce in

cultivar Waha wheat cultivar any increase in 1000-grain weight (Karam et al., 2009). In fact, this trait depend to the number of spike/m^2, its increase augment the competition inter and intra plant, higher rates of nitrogen fertilization leads to higher vegetative growth but decline grain weight (Shah et al. 2011). Lowest grain yield was obtained in control plots (N_0). These results corroborate those of Shah et al. (2011) but, Karam et al. (2009) establish that nitrogen treatment of 100 kg N/ha had the lowest yield (3770 kg/ha) in two durum wheat cultivars. According Weisz *et al.* (2007) and Hussain et al. (2006), nitrogen rate induces generally a raise of wheat growth and plant high. However, the maximum applied N level was insufficient to optimize yield of durum wheat. Abedi et al. (2011) reported that high grain yield was obtained (8230 kg ha-1) using 240 kg Nha-1 compared to control (3930 kg ha-1). Marino et al. (2009) and Noureldin et al. (2013) concluded that the increase of N rate increase grain yield, biomass accumulation and decreased 1000 grain weight. These results corroborate with them of Mandic et al. (2015). According to Mantai et al. (2015) showed that the use of nitrogen using quadratic regression model on the grain yield and harvest index, in oat showed linear behavior in the biological yield and straw.

Nitogen use efficiency increase with the increase on nitrogen rates, maximum values were obtained under N4 treatment (140 kg N ha^{-1}). Jamaati-e-Somarin et al. (2010) concluded that nitrogen supply reduce nitrogen use efficiency. The greatest and the lowest agronomical nitrogen use efficiencies were obtained in the 60 and 180 kg/ha of nitrogen. NUE was decreased with increasing nitrogen fertilization levels. Best values was noted at the level of 100 kg N ha^{-1}, which is consider as rational application taking into account nitrogen emissions in the environment (Vukovic et al., 2008).

All measured traits were greater in Bousselem than in Kef site. It's due to the monthly rainfall variability and quantity between the two sites. Tilling et al. (2007) confirmed that wheat response to nitrogen supply is so related to rainfall distribution. Highest difference was noted from December to March, when rainfall in Bousselem site was

more than the double of those unregistered in Kef site. Karam et al. (2009) reported that this period, is characterized by a competition between vegetative and reproductive organs for limiting resources, mostly water, for wheat.

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