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Response of Some Bread and Durum Wheat Genotypes to Different Levels of Nitrogen in South West of Iran

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ABSTRACT

In order to identify the effects of different levels of nitrogen fertilizer on seed yield and seed growth indices of some bread and durum wheat genotypes, a field experiment was conducted in 2013-2014 in Khuzestan Agricultural and Natural Resource Research Center. The experiment was designed as a split plot with three replications. Nitrogen application rates (50, 100 and 150 kg $N.ha^{-1}$) were assigned in the main plots and the sub plots consisted of six wheat genotypes (Bread; Verinak, Star, Chamran and Durum; Karkheh, D-84-5, D-83-8). Results indicated that seed yield, seed protein percentage, seed effective filling rate, remobilization of dry matter and the current photosynthesis, 1000 seed weight and seed effective filling period between genotypes were significant. Maximum and minimum seed filling rate was related to Karkheh genotype in 150 kg $N.ha^{-1}$, and Verinak in treatment of using 50 kg $N.ha^{-1}$. The effect of nitrogen levels on seed effective filling period was not significant. The maximum duration of seed filling was devoted to Verinak genotype and the minimum one was for Karkheh genotype. Chamran genotype, by using 150 kg $N.ha^{-1}$, had maximum seed yield while Verinak genotype, using 50 kg $N.ha^{-1}$ had minimum seed yield. Maximum 1000 seed weight was devoted to Karkheh genotype in treatment of using 150 kg $N.ha^{-1}$, also the minimum 1000 seed weight was that of Star genotype in treatment of using 100 kg $N.ha^{-1}$. The maximum seed protein percentage was observed at D-84-5 line, in 150 kg $N.ha^{-1}$, and minimum amount of protein was in Chamran and Karkheh in 50 kg $N.ha^{-1}$. A positive and significant correlation observed between seed yield and seed weight, the current photosynthesis rate and remobilization rate. In general, according to Khuzestan climate conditions, planting Chamran genotypes by using 150 kg $N.ha^{-1}$, can led to an appropriate yield and it is highly suggested.

Keywords: *Nutrition, Remobilization, Seed filling period, Yield.*

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INTRODUCTION

Cereals, including wheat and barley, are of primary importance for the food security in the 21st century (Distelfeld *et al*., 2014). Globally, wheat is one of the most important crops providing over 20% of the calories consumed by the world's population and a similar proportion of protein by about 2.5 billion people (Braun *et al*., 2010). Wheat produce more than 50 percent of requirements protein and calorie for human nutrition in Iran. Management of nitrogen fertilizing is important to increasing wheat production. So, among chemical fertilizer a high correlation reported between nitrogen and yield. Increasing nitrogen application induced increasing leaf area, tiller formation and leaf area index (Tahmasebi Sarvestani *et al*., 2003). Nitrogen deficiency in the wheat plant may be due to: decrease in fertilizer usage, using organic methods of crop management (David, 1997) and nitrogen consumption in an inappropriate time (Mainard *et al*., 2001). In these conditions number of seeds per area unit (Modhej and Mojadam, 2006) will be decreased because of decrease in number of spikes per area unit, number of spikelet per spike, number of fertile florets in spikelet, decrease of survival and decrease in fertilization of florets (Peltonen and Peltonen, 1995). Some researches realized nitrogen fertilizer can increase vegetative growth and seed yield. A desirable increase of nitrogen can expand the most important factor of seed yield, number of seeds per spike (Khalilzadeh *et al*., 2013; Fang *et al*., 2010). Modhej and Mojadam (2006) reported that, biological yield is one of the traits which deeply decrease when nitrogen decrease. The redistribution of the substances stored in transient sources to the sink organs is called remobilization (Gardner *et al*., 2003). Improving the capacity for supporting grain filling by stem and spike reserves is an important physiological trait and breeding target in wheat. Studies have shown that reserve remobilization could contribute to 5–20% of the final grain yield under non-stress conditions, while it might rise to 40–60% under stressful growing conditions (Blum, 1998). The carbon (C) necessary for grain filling in wheat comes from three sources: current assimilation; remobilization of pre-anthesis assimilates stored in the stem and other parts of the plant; and retranslocation of assimilates stored temporarily in the stem after anthesis. To understand the reduction in grain yield arising from post-anthesis water deficits, it is necessary to identify which of these sources of C is limiting the grain-filling process (Ercoli *et al*. 2008). On the whole, about 10% to 30% of the stem carbohydrates which are extant before and after anthesis are sent to the grain-bearing organ; this remobilization can be more than 70% in some grain crops (Wang *et al*., 1995; Setter *et al*., 1998). Decrease in seed filling duration can reduce seed filling by carbohydrates and increase of protein ratio to carbohydrate in seeds (Subedi *et al*., 2007). Ehdaie *et al*. (2006) noted that wheat crops in dry land areas may depend more on stem reserves for grain filling than on current photosynthesis. In high levels of nitrogen consumption, due to productivity of more leaves and their persistence, because of having high amount of current photosynthesis, have decrease in amount of redistribution (Mohammadi *et al*., 2015). Early-maturing genotypes, due to the fact that they start their productivity sooner, have a better chance for seed filling and growth. But late - maturing genotypes, due to their late productivity, and because their growth period meets heat at the end of the season, devote less time to their seed filling and growth (Abedi *et al*., 2011). Golabadi *et al*. (2015) was evaluating response of wheat genotypes under drought stress and different rate of nitrogen. Their result showed the highest values of spike and stem contribution to grain yield were obtained under drought stress while current photosynthesis was found to be the sole supplier for seed filling in normal conditions. Application of extra nitrogen fertilizer under drought stress was found to reduce the loss of seed yield in some genotypes as a result of enhanced vegetative growth, reserve accumulation, and dry matter remobilization to the seed. Pre-anthesis stored dry matter in wheat (*Triticum aestivum* L.) is important in a Mediterranean climate because grain filling greatly depends on the remobilization of pre-anthesis assimilates. Bahrani *et al*. (2011) demonstrated that grain-filling rate of wheat, while affected by water deficit, is maintained above what is expected from post-anthesis dry matter accumulation because remobilization of assimilates to the grain continued despite a reduction in C assimilation. Stems were more important than the other parts of the plant in the remobilization of dry matter to the grain during the grain-filling period. The excessive use of N in Iran results in unfavorably delayed senescence. Early senescence induced by water stress could increase the rate of grain filling and improve kernel weight in this case. It was concluded that the stored carbohydrate had provided an important buffer against water stress during grain filling, in terms of yield. Naseri *et al*. (2010) reported that the highest grain yield and biologic yield were obtained in 160 and 240 kg $N.ha^{-1}$ with 5100 and 14360 $kg.ha^{-1}$, respectively. Although in material movement process from the source to the sink the vascular system is not restricting, but due to the fact that in remobilization process in both parts of material accumulation in the vegetative parts while their movement and remobilization, energy will be consumed, therefore any increase in photosynthesis persistency and the accumulation of materials will be preferred to materials remobilization (Flood *et al*., 1995). Management of nutrients, especially nitrogen, in order to wheat economic production and maintain sustainable agriculture and to provide food security, is considered to have an important priority. Despite importance of environmental stresses such as lack of nitrogen in arid and semi-arid regions such as Khuzestan province and most regions of Iran country, enough studies have not been done to evaluate the effect of lack of this element on wheat genotypes. Therefore it is essential to know morphophysiologic features such as function of photosynthesis organs, seed growth process, determining proportion of remobilization and current photosynthesis in growth and seed filling process is necessary for genotypes. Therefore this research has been conducted in order to study different effects of nitrogen deficiency on some bread and durum wheat genotypes.

MATERIALS AND METHODS

Field and treatment information

This research was conducted in 2013-2014 agronomic season via split plot experiment based on randomized complete block designs with three replications, in Experimental Field of Khuzestan Agricultural and Natural Resource Research Center, southwest of Iran (32°20' N, 40°20' E and altitude 22.5m) with moderate winters and hot summers. Four levels of nitrogen fertilizer (50, 100 and 150 kg $N.ha^{-1}$) were assigned in the main plots and the subplots consisted of six wheat genotypes (Bread: Verinak, Star, Chamran and

Durum: Karkheh, D-84-5, and D-83-8). According to research recommendations, planting density was 400 seeds per square meter for bread wheat, and 500 seeds per square meter for durum varieties. Physical and chemical properties of field soil were shown in table 1.

Table 1. Physical and chemical properties of the field soil

Soil depth (cm)	0-30	30-60
Acidity (pH)	8.46	8.50
Electrical conductivity ($ds.m^{-1}$)	4.07	2.69
Organic carbon (%)	0.507	0.351
Absorbable Phosphorus (ppm)	8	7
Absorbable potassium (ppm)	180	170
Clay (%)	24	24
Silt (%)	42	42
Sand (%)	34	31
Soil texture	Loam	Loam

Traits measurements

In order to investigate the process of seed growth in different treatments and to determine duration and rate of seed filling, one week after main spike appearance, some of the main stems were identified by colored ribbons. Seven days after pollination, every 5 days, and five marked spikes were gathered randomly, and from each spike, 5^{th} to 9^{th} spikelet was taken, and then two seeds were taken from each spikelet which was closer to the center. Dry weight of the seeds was measured after oven for 48 hours in 65 degrees centigrade. After drawing the curve of seed growth (seed weight as a function of days after flowering) from each curve four spots were chosen which were in linear seed growth stage. Then regression analysis was conducted for two variables of days after flowering and dry matter of the seed. Regression coefficient which was achieved indicated "seed effective filling rate" according to milligram in seed. Seed effective filling period was calculated by the following equation (Ellis and Pieta-Fllho, 1992):

Equation 1. Average seed weight at final harvest= Seed effective filling period/ Seed effective filling rate

Kjeldahl method was used to determine the amount of plant nitrogen. Finally, nitrogen percentage was calculated as follow (Sosulski and Imafidon, 1990):

Equation 2. Protein percentage= Nitrogen percentage* 5.7

The rate of remobilization and current photosynthesis were evaluated via the following formulas (Royo *et al*., 1999):

Equation 3. Dry matter remobilization rate (g/plant) =

Dry weight of vegetative organs at the pollination stage (g/plant) – dry weight of vegetative organs at the maturity stage (g/plant)

Equation 4. Current photosynthesis Rate (g/plant) =Seed yield (g/plant) – Dry matter remobilization rate (g/plant)

Equation 5. Remobilization contribution= (Dry matter remobilization rate / seed yield) * 100

Equation 6. Current photosynthesis contribution= (Remobilization contribution– 100)

Statistical Analysis

The analysis of variance was done by Minitab software (Ver.15) and the means were compared using Duncan's multi range test at 5% probability level.

RESULT AND DISCUSSION

Seed yield

Result of Analysis of variance showed effect of different levels of nitrogen and genotypes on seed yield was significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). According to the results of mean comparison decrease of nitrogen consumption led to significant decrease of seed yield, although the highest and the lowest amount of seed yield belonged to 150 kg $N.ha^{-1}$ (4764 $kg.ha^{-1}$) and 50 kg $N.ha^{-1}$ (3903 $kg.ha^{-1}$) (Table 3). Some researchers reported the increase of nitrogen causes a significant increase of the number of tillers per plant and fertilized tillers, leaves surface and durability of flag leaf, biological yield, number of spike per square meter and number of seeds per spike and the positive and significant effects of these traits on the seed yield, also a positive correlation between the number of seeds per spikelet and the number of spikelet per spike with the seed yield (Ehdaie and Waines, 2001; Kumar *et al*., 2001). Mean comparison of seed yield in studied genotypes indicated that Chamran genotype with 4680 kg per hectare had the highest seed yield and Verinak and Star with 4150 and 4240 kg per hectare, had the lowest seed yield. Chamran genotype is tolerate the environmental conditions of Khuzestan province, and due to high spikes in area unit and also the number of seeds per spike, has high yield (Table 4).

1000- Seed weight

According to the result of analysis of variance effect of genotypes on 1000-seed weight was significant at 1% probability level, but effect of different levels of nitrogen and interaction effect of treatments was not significant (Table 2). Mean comparison of 1000-seed weight in studied genotypes revealed that Karkheh (48 gr) and Star (30 gr) had the highest and the lowest seed weight, respectively. Also durum genotypes than bread had higher 1000 seed weight (Table 4), these results were consistent with the reports of Modhej *et al*. (2008). The reason was the fewer numbers of seeds in these genotypes and thus allocating more treated substances to fewer sinks and ultimately related with increasing the weight of seeds (Table 3).

Seed protein percentage

Differences in the protein percentage of seeds were significant for nitrogen levels, genotypes and the interaction effects of nitrogen and genotype at 1% probability level (Table 2). According to the results achieved by this experiment, lack of nitrogen decreases protein percentage of the seeds, so the highest and the lowest amount of protein percentage belonged to 150 kg $N.ha^{-1}$ (12.9%) and 50 kg $N.ha^{-1}$ (11.6%) (Table 3). Mean comparison of the seed protein at maturity stage in the studied genotypes indicated that the highest and the lowest amount of seed protein was allocated to Durum line D-84-5 (13.2%) and to Verinak (11.5%) bread wheat respectively (Table 4). Nasseri *et al*. (2009) reported the protein yield increased with increasing in nitrogen application rates so the highest protein yield (701 $kg.ha^{-1}$) produced by nitrogen rate of 90 $kg.ha^{-1}$.

Current photosynthesis rate

According to the results of analysis of variance effect of different level of nitrogen and genotypes on current photosynthesis rate was significant at 5% and 1%, respectively, but interaction effect of treatments was not significant (Table 2). Mean comparison result of different levels of nitrogen revealed maximum and minimum rate of current photosynthesis was allocated to 150 kg $N.\ ha^{-1}$ (299.7 $gr.m^{-2}$) and 50 kg $N.\ ha^{-1}$ (272.7 $gr.m^{-2}$), respectively (Table 3). Nitrogen increases current photosynthesis rate due to producing more leaf area and its more durability, through delaying aging in leaves (Yang *et al*., 2001; Ayadi *et al*., 2014). Also nitrogen increases fertilized tillers, number of spikes and fertilized florets provides stronger sinks for receive treated substances crated by photosynthesis.

Table 2. Summary of analysis of variance of measured traits

S.O.V	df	Seed yield	1000 seed weight	Seed protein percentage	Current photosynthesis rate	Remobilization rate	Seed effective filling rate	Seed effective filling duration
Replication	2	1016.9^{ns}	44.24^{ns}	1.3^{ns}	6998.7^{ns}	3557^{ns}	0.006^{ns}	0.43^{ns}
Nitrogen	4	33685.8**	68.24^{ns}	6.82**	3345.7*	16466.7**	0.11**	0.76^{ns}
Error I	4	3037.1	37.36	0.001	396	1395.7	0.007	1.17
Genotype	5	3457.8**	321.2**	2.29**	1736.1**	10926.1**	0.392**	24.05**
Nitrogen* Genotype	10	1216.6^{ns}	40.5^{ns}	0.28^{ns}	2173.1^{ns}	602.03^{ns}	0.013^{ns}	4.63^{ns}
Error II	30	1036	17.5	0.001	702.8	533.9	0.008	1.12
CV (%)		7.3	8.82	2.33	7.38	9.33	5.1	4.2

^{ns}, * and ** : Non Significant, significant at the 0.05 and 0.01 probability level, respectively.

Table 3. Mean comparison effect of different level of nitrogen on measured traits

Treatment	Seed yield (Kg.ha^{-1})	1000 seed weight (gr)	Seed protein (%)	Current photosynthesis rate (gr.m^{-2})	Remobilization rate(gr.m^{-2})	Seed effective filling rate (mg.day^{-1})	Seed effective filling duration (day)
Nitrogen							
150 kg.ha^{-1}	4764^{a}	40.5^{a}	12.9^{a}	299.7^{a}	176.6^{a}	1.85^{a}	20.4^{a}
100 kg.ha^{-1}	4406^{ab}	37.0^{a}	12.4^{b}	282.6^{ab}	157.9^{b}	1.73^{b}	20.4^{a}
50 kg.ha^{-1}	3903^{b}	39.0^{a}	11.6^{c}	272.7^{b}	117.4^{c}	1.70^{b}	20.05^{a}

* Means followed by similar letters have not significantly different ($p<0.05$) – Using Duncan Test.

Table 4. Mean comparison effect of different genotype (Bread and Durum) on measured traits

Treatment	Seed yield (Kg.ha^{-1})	1000 seed weight (gr)	Seed protein (%)	Current Photosynthesis Rate (gr.m^{-2})	Remobilization rate(gr.m^{-2})	Seed effective filling rate (mg.day^{-1})	Seed effective filling duration (day)
Genotypes							
Verinak	4150^{b}	38^{bc}	11.5^{f}	261.8^{c}	153^{b}	1.6^{c}	22.32^{a}
Star	4240^{b}	30^{d}	12.4^{c}	249.5^{c}	174.2^{ab}	1.65^{c}	19.08^{d}
Chamran	4680^{a}	35.5^{c}	12.2^{d}	298.4^{b}	169.3^{ab}	1.75^{b}	19.93^{dc}
Karkheh	4260^{ab}	48^{a}	12.5^{b}	238.7^{d}	187.1^{a}	2.17^{a}	17.92^{e}
D-84-5	4500^{ab}	41^{b}	13.2^{a}	356.6^{a}	93.4^{d}	1.64^{c}	20.16^{bc}
D-83-8	4320^{ab}	39^{bc}	12^{e}	305^{b}	127.1^{c}	1.74^{b}	21.61^{ab}

* Means followed by similar letters have not significantly different ($p<0.05$) – Using Duncan Test.

Mean comparison of different genotypes showed that D-84-5 genotype has allocated the maximum amount of photosynthesis rate (356.6 $gr.m^{-2}$), while Karkheh had the minimum rate (238.7 $gr.m^{-2}$) (Table 4). The higher surface of flag leaf and the leaf durability in D-84-5 genotype, increases current photosynthesis rate.

Remobilization rate of photosynthesis to seed

Result of analysis of variance indicated effect of different levels of nitrogen and genotypes on remobilization rate of photosynthesis materials was significant at 1% probability level, but interaction effect was not significant (Table 2). According to the results of mean comparison of different levels of nitrogen, maximum and minimum remobilization rate belonged to 150 kg $N.ha^{-1}$ (176.6 $gr.m^{-2}$) and 50 kg $N.ha^{-1}$ (117.4 $gr.m^{-2}$), respectively (Table 3). The average remobilization of photosynthetic materials in the genotypes, recognized that Karkheh genotype had maximum (187.1 $gr.m^{-2}$), and D-84-5 had minimum amount of remobilization (127.1 $gr.m^{-2}$) (Table 4). Current photosynthesis rate of Karkheh genotype was lower than other genotypes. Increasing remobilization rate in the filling seed stage in this genotype compensates the lack of current photosynthesis, in order to the plant yield not to decline. The effect of sink reduction was contrary, indicating that grain sink size was not a great factor to limit the production of photosynthates, but it can controlled the partitioning of photosynthates. Wang *et al.* (1997) confirmed this finding.

Seed effective filling rate

Result of analysis of variance showed the effect of different levels of nitrogen and different genotypes on seed effective filling rate was significant at 1% probability level, but interaction effect was not significant (Table 2). Mean comparison of different levels of nitrogen revealed that 150 $kgN.ha^{-1}$ achieved maximum amount of seed effective filling rate (1.85 $mg.day^{-1}$) against another nitrogen level treatments, decrease of nitrogen from 150 kg to 100 kg per hectare led to significant decrease of seed effective filling rate (Table 3). Mean comparison of different genotypes indicated maximum and minimum seed effective filling rate belonged to Karkheh (2.17 $mg.day^{-1}$) and Verinak (1.6 $mg.day^{-1}$) (Table 4). Increasing the amount of nitrogen fertilizer led to increase of leaf photosynthesis and consequently, increase of the seed effective filling rate (Fredrick and Camperato, 1994; Simons, 1982). Correlation of remobilization rate and contribution with seed effective filling rate was positive and significant (Table 5). Generally, the average rate of seed filling in Durum genotypes was more than bread genotypes (Mandic *et al.*, 2015). Yang *et al.* (2001) concluded that senescence induced by controlled soil drying during grain filling can promote the remobilization of presorted assimilates to the grains, accelerate grain filling, and improve yield in cases where senescence is unfavorably delayed by heavy use of nitrogen.

Seed effective filling duration

According to the results of analysis of variance effect of different genotypes on seed effective filling duration was significant at 1% probability level, but effect of different levels of nitrogen and interaction effect was not significant (Table 2). Mean comparison of different genotypes indicated the highest average of seed effective filling duration belonged to Verinak genotype (22.32 day) and the lowest one belonged to Karkheh genotype (17.92 day) (Table 4). In general, since early maturation genotypes begin earlier reproductive stages, they have more time for growth and filling the seed, whereas delayed genotypes have less time for filling and growth of the seed due to their delay in beginning reproductive stages and coincidence of developmental stages and seed growth with the heat of the end of season (Modhej and Lack, 2011). In this research, it was recognized that durum genotypes had more time dedicated to filling the seed (Table 4). Positive correlation between these attributes indicated that increasing nitrogen leads to the increase of leaf photosynthesis, more storage and transitivity of materials and greater amount of transferred material to the seed, when the plant has little time to fill the seed, and current photosynthesis is not able alone to grow the seed, remobilization can supplement the growth and filling of seed in shorter time. The highest and the lowest rate of seed filling belonged to Karkheh and Verinak respectively.

Table 5. Correlation coefficient between measured traits

Traits	Seed yield	Seed weight	Current photosynthesis rate	Seed protein	Remobilization rate	Seed effective filling duration	Seed effective filling rate
Seed yield	-						
Seed weight	0.51*	-	-	-	-	-	-
Current photosynthesis rate	0.58*	0.030	-	-	-	-	-
Seed protein	0.046	0.08	0.77**	-	-	-	-
Remobilization rate	0.49*	-0.06	-0.51*	-0.91**	-	-	-
Seed effective filling duration	0.036	-0.08	0.78**	-0.99**	0.91**	-	-
Seed effective filling rate	0.202	0.74**	-0.74**	0.38*	0.62*	-0.54*	-

^{ns}, * and ** : Non Significant, significant at the 5% and 1% probability level, respectively.

Correlation between traits

Correlation coefficients of seed effective filling rate and duration, seed yield, seed weight, remobilization and current photosynthesis are presented in Table 5. There was non significant correlation between seed yield and seed growth components such as rate and duration of seed filling, but among these traits, seed filling rate had a higher correlation with the seed yield. Also seed yield has significant correlation with seed weight (0.51*), current photosynthesis rate (0.58*) and remobilization rate (0.49*) (Table 5). Results showed that the correlation between seed effective filling rate and duration was significant and negative (-0.54*) (Table 5). Royo *et al*., (1999) quoted that correlation between rate and duration of seed filling was negative. Correlation of seed weight and seed effective filling rate was positive and significant (0.74**) (Table 5). Matrix of the correlation coefficients showed that correlation of remobilization with seed filling rate was positive and significant (0.62*) (Table 5). If the storage of photosynthetic materials is greater, the remobilization and volume of transferred material to the seed is higher, and more material will transferred to the seed at the same time. Any factor causing further transitivity to seed increases the seed filling rate and finally improves the seed yield (Yang *et al.*, 2000). In this research correlation between the current photosynthesis rate and seed effective filling duration was positive and significant (0.78**).

CONCLUSION

The effect of different levels of nitrogen and genotype was significant on seed yield, dry matter remobilization, current photosynthesis, contribution of remobilization and current photosynthesis. Chamran variety had maximum and Verinak variety had minimum seed yield among genotypes. An increase on amount of nitrogen from 50 to 150 Kg $N.ha^{-1}$ had no significant effect on weight and growth of the seed. Seed effective filling rate and duration of bread and durum wheat genotypes had different reactions to applying different amounts of nitrogen. According to climate conditions of Khuzestan, it seems that planting Chamran variety (bread wheat) and D-84-5 line (durum wheat) by 150 Kg nitrogen consumption per hectare can be suggested.

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