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Research Article

THE EFFECT OF SPLIT APPLICATION OF NITROGEN FERTILIZER AND NITROGEN LEVEL ON THE YIELD AND YIELD COMPONENTS OF BARLEY

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ABSTRACT

In order to investigate the effect of split application of nitrogen fertilizer and nitrogen level on the yield and yield components of barley, a split plot experiment in the form of randomized complete block design with four replications was carried out in the town of Vis in 2013-2014. The treatments included three levels of nitrogen (50, 90, 130kg/ha) in the main plots and split application of nitrogen (S1: Planting stage = 50%, stem elongation stage = 50%, S2: planting stage = 25%, stem elongation stage = 50%, reproduction stage = 25%, S3: planting stage = 25%, stem elongation stage = 75%) in the sub plots. The results showed that different levels of nitrogen had a significant effect on grain yield, number of spikes per area unit, number of grains per spike, and 1000-grain weight. The highest grain yield by 480.38 kg/ha and also the highest number of grains per spike, number of spikes per area unit and 1000-grain weight belonged to the treatment with130 kgNha^{-1}. The lowest grain yield by 351.68 kg/ha and also the lowest number of grains per spike, number of spikes per area unit, and 1000-grain weight belonged to the treatment with50 kgNha^{-1}. The results also showed that split application method had a significant effect on grain yield, number of spikes per area unit, and number of grains per spike so that the highest grain yield by 447.66 kg/ha and also the highest number of grains per spike, number of spikes per area unit and 1000-grain weight belonged to S3 treatment. The highest grain yield by 517.96 kg/ha belonged to the treatment with 130 kg nitrogen and S3.

Keywords: *Split Application of Nitrogen, Yield and Yield Components, Barley, Nitrogen Level*

INTRODUCTION

Grain is one of the most important food crops on the Earth that supplies 70% of the food for people around the world. In general, grain supplies more than ¾ of the energy and ½ of the protein that humans need and is the basis of nutrition and human survival (Noor *et al.,* 2007). Barley (Hordeum vulgare L.) belongs to the Poaceae (grasses) family and indirectly plays an important role in human food chain. Since barley is a relatively resistant plant to unfavorable soil conditions such as salinity its cultivation has a relative advantage over other crops and is economic (Malakooti *et al.,* 2005). Nitrogen consumption management is especially important with regard to the solubility and high mobility of nitrogen in soil and also its effects on the shoots. Shortage of nitrogen in barley makes the plant yellow and thins the stems and causes the loss of leaves and ultimately the decrease of yield (Veis, 2000). The amount of nitrogen fertilizer and the time of its consumption after sowing the plant have an important role in further growth and better yield of crop in area unit. One of the ways to increase the efficiency of nitrogen consumption is the split application of nitrogen fertilizer (Fan *et al.,* 2004). The positive and significant effect of nitrogen on the yield of barley is possible in case of proper management of nitrogen consumption (Beheshti and Behbodi, 2010). The results of many reports indicate that as the split application of nitrogen fertilizer increases, the yield increases too (Noor *et al.,* 1997). Burin *et al.,* (1989) reported that the highest grain yield in maize was achieved through the split application of 200 kg/ha nitrogen fertilizer before planting and at the stages of 4 to 6 leaves. Ike *et al.,* (2007) reported that consumption of150 kgNha^{-1} increased the grain yield and the rate of nitrogen in grain. The results of the study conducted by Askari *et al.,* (2006) showed that as the level of nitrogen increased from 0 to 150 kg, the yield of grain sorghum increased from 35.4 to 56.8 t/ha. McDonald (2000) reported that as the consumption of nitrogen fertilizer increased up to 90 kg/ha, the number of grains per spike increased too and further increase of nitrogen fertilizer consumption didn't make much change. Zebart and Sherrod (1992) reported that as the consumption of nitrogen fertilizer increased in wheat, the number of fertile tillers, number of spikes per square meter, 1000-grain weight, grain yield, and the yield of straw increased, but the number of grains per spike and the harvest index decreased. Correct and proper use of nitrogen fertilizers increased the grain yield of wheat mainly through the increase of number of spikes per area unit and the increase of number of grains per spike had a minor role in the increase of yield (Giovanni *et al.,* 2004) (Fouler and Brighton, 2001). Nitrogen increases the yield of wheat via increasing the number of spikes, the number of grains per spike, and 1000-grain weight. In general, the yield components of wheat are directly affected by nitrogen (Hatfield *et al.,* 2004). If the nitrogen is consumed before the rapid growth of plant, the nitrogen uptake and its consumption efficiency will increase and two or three split applications of nitrogen will significantly affect 1000-grain weight (Thomas *et al.*, 1991). Bahrani and Tahmasebi (2002) investigated the effect of different levels and consumption time of nitrogen fertilizer on the yield and yield components of wheat and concluded that the effect of different levels and consumption times of nitrogen on the number of fertile spike, number of grains per spike, 1000-grain weight, and grain yield was significant, so that as the nitrogen consumption increased all the above traits increased, too. The effect of increased time of split application of nitrogen on the traits was significant, as well. This research aimed to determine the best level and the most appropriate split application of nitrogen fertilizer in order to achieve the maximum yield in barley in Vis.

MATERIALS AND METHODS

Experimental Location

The experiment was carried out in Farm located in Vis Town at latitude 31°36´N and longitude 48°53´E and 50 m above the sea level. The soil of the experiment site had a clay-loam texture with pH = 7.8. The experiment was carried out as a split plot in the form of randomized complete block design with four replications. The treatments included three levels of nitrogen (50, 90, 130kg/ha) in the main plots and split application of nitrogen (S1: Planting stage = 50%, stem elongation stage = 50%, S2: planting stage = 25%, stem elongation stage = 50%, reproduction stage = 25%, S3: planting stage = 25%, stem elongation stage = 75%) in the sub plots. Land preparing operations included the land irrigation before plowing, plowing the land to the depth of 30 cm, disking to the depth of 15 cm and trowel. Each replication included 9 plots and the whole plan included 36 experimental units. Each plot consisted of 7 planting lines as long as 6 m and the space between the lines was 25 cm. The space between two sub plots was 1.5 m and every two main plots were spaced from each other by the furrower as 1.5m. The cultivar used in the study was the overall 13 cultivar of barley. During three split applications some nitrogen fertilizer was applied during the sowing after the measurement, and the rest was applied after the calculation as surplus during the stem elongation stage at experimental plots. The barley seeds were planted in September manually. The plots were harvested manually on November 6 with a sickle. Measurement of the Studied Traits: The studied traits included 1000-grain weight, number of grains per spike, number of spikes per area unit, and grain yield. In order to measure the traits during the final harvest time, the samples were taken from each plot in an area of 2 m^2 after eliminating half a meter from the beginning and end (marginal effect). The grains were separated from the straw after threshing, and then the grain yield was calculated after weighing the grains with a digital scale. 1000-grain weight was measured through random selection and manual counting of five 500-seed samples from each plot and weighing them with a digital scale. All data analyses and regression calculations were done by means of Minitab software, and Duncan's test at 1% and 5% levels was used to compare the means. The diagrams were drawn by Excel software.

RESULTS AND DISCUSSION

Number of Grains per Spike

According to the ANOVA results the effect of different levels of nitrogen fertilizer on the number of grains per spike in barley was significant at 1% probability level (Table 1). According to the mean comparison results of the simple effects of different levels of nitrogen fertilizer (Table 2), as different levels of nitrogen fertilizer increased, the number of grains per spike increased too, so that the highest number of grain per spike by 30.25 belonged to the treatment with 130 kgNha^{-1} and the lowest number of grains per spike by 25.61 belonged to the treatment with 50 kgNha^{-1}. Nitrogen deficiency at the time of plant inoculation causes lack of grading. In a study it was found that sufficient nitrogen after the beginning of spike emergence would increase the number of grains per spike (Al-Sadat, 2011). As the nitrogen consumption increases up to 90 kg/ha the number of grains per spike increases too and more increase of nitrogen consumption doesn't make noticeable changes in the number of spikes. This has been reported by other researchers, as well (Ayoob *et al.*, 1994) (McDonald, 2000). In another research, the increase of the number of grains per spike in the treatment with 90 kgNha^{-1} was due to high length of spike, number of fertile spikelet and the number of grains per spikelet (Al-Sadat *et al.*, 2011). Positive effect of nitrogen fertilizer on the number of fertile spikelet in the main spike could be due to the increase of spikelet emergence period via prolonging tiller emergence stage and the improvement of florets fertility because nitrogen and unfavorable environmental conditions during the floret development (until the emergence of flag leaf) can cause the death of some spikelet (Qranjik *et al.*, 2001). The results show that as the application of nitrogen increases, the number of grains per spike increases, too which could be attributed to the decrease of flowers loss due to the use of nitrogen. According to the ANOVA results the effect of split application of nitrogen fertilizer on the number of grains per spike in barley was significant at 5% probability level (Table 1). According to the mean comparison results of the simple effect of split application of nitrogen fertilizer on the length of pod (Table 3), it is observed that the highest number of grains per spike by 29.58 belongs to the S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage) and the lowest number of grains per spike by 26.51 belongs to the third treatment of S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage). Bahrani and Tahmasebi (2002) investigated the effect of nitrogen level and nitrogen consumption time on the yield and yield components of wheat and concluded that the effect of levels and consumption time of nitrogen on the number of fertile spike, number of grains per spike, 1000-grain weight, and grain yield was significant, so that as the consumption of nitrogen increased all the above traits increased, too. The effect of increased time of split application of nitrogen on the traits was significant, as well which is consistent with the results of the present research. According to the ANOVA results the interactive effect of different levels and split application of nitrogen fertilizer on the number of grains per spike in barley was significant at 1% probability level (Table 1). Mean comparison of the interactive effects of different levels and split application of nitrogen fertilizer showed that the highest number of grains per spike belonged to the treatment with consumption of 130kgNha^{-1} and S3 split application of nitrogen fertilizer (25% at planting time and 75% during stem elongation stage) (Table 4).

Number of Spikes per Area Unit

According to the ANOVA results the effect of different levels of nitrogen fertilizer on the number of spikes per area unit in barley was significant at 1% probability level (Table 1). According to the mean comparison results of the simple effects of different levels of nitrogen fertilizer (Table 2), as different levels of nitrogen fertilizer increased, the number of spikes per area unit increased too, so that the highest number of spikes per area unit by 360.11 belonged to the treatment with 130 kgNha^{-1} and the lowest number of spike s per area unit by 314 belonged to the treatment with 50 kgNha^{-1}. Zebart and Sherrod (1992) reported that as the consumption of nitrogen fertilizer increased in wheat, the number of fertile tillers, number of spikes per square meter, 1000-grain weight, grain yield, and the yield of straw increased which was consistent with the results of this research. According to the ANOVA results the effect of split application of nitrogen fertilizer on the number of spikes per area unit in barley was significant at 1% probability level (Table 1). According to the mean comparison results of the simple effect of split application of nitrogen fertilizer on the length of pod (Table 3), it is observed that the highest number of spikes per area unit by 357.78 belongs to the S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage) and the lowest number of spikes per area unit by 296.22 belongs to the third treatment of S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage). Correct and proper use of nitrogen fertilizers increases the grain yield of wheat mainly through the increase of number of spikes per area unit, and the increase of number of grains per spike has a minor role in the increase of yield (Giovanni *et al.,* 2004) (Fouler and Brighton, 2001). The results were consistent with the findings of this research. According to the ANOVA results the interactive effect of different levels and split application of nitrogen fertilizer on the number of spikes per area unit in barley was significant at 1% probability level (Table 1). Mean comparison of the interactive effects of different levels and split application of nitrogen fertilizer showed that the highest number of spikes per area unit belonged to the treatment with consumption of 130kgNha^{-1} and S3 split application of nitrogen fertilizer (25% at planting time and 75% during stem elongation stage) (Table 4).

1000-Grain Weight

According to the ANOVA results the effect of different levels of nitrogen fertilizer on 1000-grain weight in barley was significant at 1% probability level, but the effect of split application of fertilizer on 1000-grain weight was insignificant (Table 1). According to the mean comparison results of the simple effects of different levels of nitrogen fertilizer (Table 2), as different levels of nitrogen fertilizer increased, the weight of 1000-grain increased too, so that the highest 1000-grain weight by 32.10 belonged to the treatment with 130 kgNha^{-1} and the lowest 1000-grain weight by 26.39 belonged to the treatment with 50 kgNha^{-1}. The results indicate that nitrogen increases the weight of grains by increasing the transfer of assimilated synthesized by plant into the grains. It can also be due to the increase of plant green area and prolonging the flowering stage. Moreover, high levels of nitrogen lead to the increase of dry matter production and leaf area durability and the increase of current photosynthesis during the grain filling stage and the transfer of assimilates into grains between flowering stage and grains maturity stage increases in the treatment with consumption of 130 kgNha^{-1}. In this treatment the leaf lifetime increases after pollination and the relations between source and destination inclines more towards the destination. Salehi and Bahrani (2000) have also investigated the matter and have confirmed it. According to the ANOVA results the interactive effect of different levels and split application of nitrogen fertilizer on the weight of 1000-grain in barley was significant at 1% probability level (Table 1). Mean comparison of the interactive effects of different levels and split application of nitrogen fertilizer showed that the highest weight of 1000-grain belonged to the treatment with consumption of 130kgNha^{-1} and S3 split application of nitrogen fertilizer (25% at planting time and 75% during stem elongation stage) (Table 4). Nitrogen increases the yield of wheat via increasing the number of spikes, the number of grains per spike, and 1000-grain weight. In general, the yield components of wheat are directly affected by nitrogen (Hatfield *et al.*, 2004) (Davis *et al.,* 2002).). If the nitrogen is consumed before the rapid growth of plant, the nitrogen uptake and its consumption efficiency will increase and two or three split applications of nitrogen will significantly affect 1000-grain weight (Thomas *et al.*, 1991). Nitrogen uptake during and after spike emergence less significantly increases the yield because the number of tillers and the number of grains per spike have been specified by that time and the yield potential has been largely determined.

Table 1: Summary of the ANOVA results of mean squares of the studied traits in barley

Grain yield	1000-grain weight	Number of spikes per area unit	Number of grains per spike	Df	Source of variation
94.82^{ns}	11.22^{ns}	72.89^{ns}	15.67n.s	2	**Replication**
463.25**	31.25**	245.57**	49.82**	2	**Nitrogen fertilizer**
110.82	8.82	60.61	13.26	4	**Error 1**
439.67**	13.22^{ns}	263.77**	25.8*	2	**Split application**
421.18**	44.18**	237.22**	53.2**	4	**Interactive effect**
93.62	7.62	72.14	11.58	12	**Error**
11.93	8.82	12.44	8.77	**(CV %)**	

*ns, **, and *: mean squares of the treatments are respectively non-significant and significant at 1% and 5% probability level.*

Nitrogen availability at the end of the season in some cases under the nitrogen limitation conditions increases the yield via increasing the grain size. Of course the increase of grain weight is not much able to compensate for the reduction of the number of tillers or the number of grains per spike (Mousavi *et al.*, 2011).

Table 2: Mean comparison results of the studied traits in barley affected by consumption of different levels of nitrogen fertilizer

Grain yield (g/m2)		1000-grain weight (g)		Number of spikes per area unit		Number of grains per spike		Nitrogen fertilizer
351.68	c	26.39	b	314.00	c	25.61	b	**50 kg/ha**
412.00	b	31.02	a	328.78	b	29.10	a	**90 kg/ha**
480.38	a	32.10	a	360.11	a	30.25	a	**130 kg/ha**

According to Duncan's test, the means with similar letters in each column are not significantly different at5% probability level.

Grain Yield

According to the ANOVA results the effect of different levels of nitrogen fertilizer on the grain yield in barley was significant at 1% probability level (Table 1). According to the mean comparison results of the simple effects of different levels of nitrogen fertilizer (Table 2), as different levels of nitrogen fertilizer increased, the grain yield increased too, so that the highest grain yield by 480.38 belonged to the treatment with 130kgNha^{-1} and the lowest grain yield by 351.681 belonged to the treatment with50 kgNha^{-1}. Nitrogen application in comparison with the control treatment increased the number of tillers, biomass production, yield and yield components of wheat (Gullic *et al.*, 2005). According to the ANOVA results the effect of split application of nitrogen fertilizer on the grain yield in barley was significant at 1% probability level (Table 1). According to the mean comparison results of the simple effect of split application of nitrogen fertilizer on the length of pod (Table 3), it is observed that the highest grain yield by 447.66 belongs to the S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage) and the lowest grain yield by 379.25 belongs to the third treatment of S3 split application of fertilizer (25% at planting stage and 75% at stem elongation stage). With regard to the further application of nitrogen and in compliance with the plant need (S3 split application), due to high nitrogen uptake and production potential of yield components and the increase of leaf area index and leaf lifetime at the beginning of flowering stage until the grain maturity, the positive correlation between the number of grains per spike and 1000-grain weight and grain yield and also the increase of grain weight and number of grains per spike due to the increase of nitrogen consumption and consequently the increase of grain yield were predictable.

According to the ANOVA results the interactive effect of different levels and split application of nitrogen fertilizer on the grain yield in barley was significant at 1% probability level (Table 1). Mean comparison of the interactive effects of different levels and split application of nitrogen fertilizer showed that the highest grain yield belonged to the treatment with consumption of 130kgNha^{-1} and S3 split application of nitrogen fertilizer (25% at planting time and 75% during stem elongation stage) (Table 4). Grain yield potential is mainly affected by nitrogen availability during vegetative growth stages. Nitrogen availability is the most influential factor on the wheat grain protein content. The increase of nitrogen supply during the vegetative growth stage increases the grain yield and protein. The required nitrogen to achieve acceptable levels of protein is more than the required level to maximize the yield. Application of all the required nitrogen to maximize the yield and to achieve acceptable levels of protein during the vegetative growth stage might lead to the excessive increase of vegetative growth and decrease of yield (Mousavi *et al.*, 2011). In another study in Montana it was found that the barely yield due to the use of 33.6 kgNha^{-1} along with the seeds was about 250 kg/ha more than its overall yield. Of course, the difference was not significant statistically (Jackson and Dubbs, 1987).

Table 3: Mean comparison results of the studied traits in barley affected by different split applications of nitrogen fertilizer

Grain yield (g/m2)		**1000-grain weight (g)**		**Number of spikes per area unit**		**Number of grains per spike**		**Split application**
379.25	c	29.51	a	296.22	c	26.51	b	**S1**
417.16	b	29.64	a	348.89	b	28.86	a	**S2**
447.66	a	30.36	a	357.78	a	29.58	a	**S3**

According to Duncan's test, the means with similar letters in each column are not significantly different at5% probability level.

Table 4: Mean comparison results of the studied traits in barley under the interactive effects of different levels and split application of nitrogen fertilizer

Grain yield (g/m2)		**1000-grain weight (g)**		**Number of spikes per area unit**		**Number of grains per spike**		**Split application**	**Nitrogen fertilizer**
351.11	F	21.05	e	168.67	i	24.06	d	S1	**50 kg/ha**
351.88	F	28.15	cd	225.00	fg	24.72	d	S2	
352.05	f	29.48	c	263.33	c	28.05	b	S3	
355.33	f	27.06	d	203.67	h	25.00	cd	S1	**90 kg/ha**
407.70	e	31.05	b	231.33	ef	29.41	b	S2	
472.96	c	35.45	a	278.33	b	32.45	a	S3	
431.30	d	28.00	cd	220.00	g	26.48	c	S1	**130 kg/ha**
491.88	b	32.41	b	250.00	d	31.81	a	S2	
517.96	a	35.88	a	313.33	a	32.88	a	S3	

According to Duncan's test, the means with similar letters in each column are not significantly different at5% probability level

Conclusion

The results indicated that different levels of nitrogen had a significant effect on grain yield, number of spikes per area unit, number of grains per spike, and 1000-grain weight. The highest grain yield by 480.38 kg/ha and also the highest number of grains per spike, number of spikes per area unit, and 1000-grain weight belonged to the treatment with consumption of 130kgNha^{-1}. The lowest grain yield by 351.68 kg/ha and also the lowest number of grains per spike, number of spikes per area unit, and 1000-grain weight belonged to the treatment with consumption of 50 kgNha^{-1}.

The results also showed that split application of nitrogen had a significant effect on the grain yield, number of spikes per area unit, and number of grains per spike so that the highest grain yield by 447.66 kg/ha, as well as the highest number grains per spike, number of spikes per area unit and 1000-grain weight belonged to S3 treatment of split application of nitrogen.

The highest grain yield by 517.96 kg/ha belonged to the treatment with consumption of 130 kgNha^{-1} and S3 treatment.

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