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Effect of Irrigation and Nitrogen levels on Yield and some traits of Barley

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ABSTRACT: To evaluate grain yield, morphological traits and grain moisture of barley cv. Karoun in Kavir (*Hordeum vulgaris* L.), an experiment was conducted in experimental farm of Islamic Azad University of Birjand, Iran in 2014 as a split-plot experiment based on a Randomized Complete Block Design with three replications. The main plots were devoted to irrigation at four levels of full irrigation and irrigation withdrawal at flowering, at grain-setting and at both flowering and grain-setting. The sub-plots were devoted to nitrogen fertilization levels at four levels of 0, 75, 150 and 225 kg ha^{-1}. Analysis of variance showed that the effect of irrigation and N fertilization levels was significant on yield, but plant height and spike length were only affected by N level. Means comparison revealed that irrigation withdrawal at flowering, at grain-setting and at both flowering and grain-setting resulted in the loss of barley grain yield as compared to full irrigation by 40.3, 31.19 and 52.87%, respectively. In addition, the increase in N rate from 0 to 150 kg ha^{-1} resulted in significant increase in plant height and spike length by 20.2 and 22.2%, respectively. The highest grain yield (2012 kg ha^{-1}) was obtained by the application of 150 kg N ha^{-1} and the increase in N fertilization level significantly increased it. According to the results, it is recommended to fertilize barley fields with 150 kg N ha^{-1} and to treat them with full irrigation in regions with climates similar to Birjand.

Keywords: barley, irrigation withdrawal, nitrogen, yield, morphological traits.

INTRODUCTION

Barley (*Hordeum vulgar* L.) is an important grain in central and western Asia and northern Africa where barley is usually grown in rain-fed system. Therefore, it suffers from water deficiency in growing season, especially in late growing season which is concurrent with drought period (Sarkar *et al.,* 2004). Barley due to its drought resistance is one of the most widely grown crops in arid and semiarid regions of the world (Ghazi *et al.,* 2007; Kinaci and Kinaci, 2005). It is the second most important grain in Iran after wheat (Irannejad, 2005).

Water deficiency is a limiting factor of plants growth and development in arid and semi-arid regions. Precise study and understanding of water and plant relations and the factors influencing them can greatly help the sound use of nature, its water resources and precipitation for meeting plants' water requirement and food production (Maghsoudi Mood, 2008). If the water requirement of a plant is not fully met in a part of and whole growing period, it will suffer from moisture stress and a part of its physiological activity will be disrupted resulting in so much loss of intra-tissue and cellular water that its growth will be stunted (Bakhshi Khaniki *et al.,* 2007).

Water is significant in plant nutrition absorption and transport process (Patane and Cosentino, 2010).

The first effect of water deficit is reducing leaf number (Golombek and Al-Ramamneh, 2002) and leaf area of every plant (Nagaz *et al.,* 2009) and then yield and dry matter production (Wang *et al.,* 2006). Many researchers found water deficit reduced the leaf area (Pandey *et al.,* 2000), plant height (Soler *et al.,* 2007), shoot growth (Stone *et al.,* 2000) and plant yield (Payero *et al.,* 2006).

Drought stress during different stages of growth in rainfed and terminal stages in irrigated cereals is the primary limitation to reduced performance of these crops (Siosemardeh *et al.,* 2006). Barley production in Iran is limited by terminal drought stress and in these critical stages of growth the need to understand the effects of nitrogen deficiency on physiological characteristics of barley is necessary (Yazdchy, 2008).

Nitrogen is the most important element that plays role in the structure of various protein molecules, enzymes, coenzymes, nucleic acids and cytochrome and is a necessary component of chlorophyll (Shafe *et al.,* 2011). This element influences the vegetative and reproductive growth and impacts leaf area, number of spikes, number of grains and grain yield (Nahvi *et al.,* 2012).

The increase in N application resulted in the increase in grain yield by improving yield components, especially the number of spikes per unit area (Ghasemi, 2012). Plant response to nitrogen fertilizer in semi-arid conditions is dependent on soil water capacity, drought intensity and time of occurrence and amount of nitrogen (Wu *et al.,* 2008). Drought stress indirectly affects crop growth through impact on nutrient absorption including nitrogen (Pugnaire *et al.,* 1999).

Kumar (2005) reported that the number of total tillers plant^{-1} was significantly increased with increasing nitrogen rate. The results of Entezami *et al.* (2014) showed that the highest of grain yield in barley was achieved in application of 50 kg N ha^{-1} fertilizer and had significantly different from other treatments, but the lowest of this factor related to control (N=0). On the other word, consumption of 50 kg N ha^{-1} is sufficient for the plant needs and produce maximum yield. Ryan et al. (2009) also reported similar results for barley.

Different doses of nitrogen significantly influenced the grain yield and yield parameters. For the highest grain yield, nitrogen doses of 100 kg N ha^{-1} were the best treatment when considering nitrogen fertilizer only. Irrigation regimes also have significant effect on yield and growth parameters of wheat. The combination of 200 mm irrigation and 120 kg N ha^{-1} is the best treatment for optimal production of wheat (Shirazi *et al.,* 2014). According to Karam *et al.* (2009), about 50% of soil water deficit as supplemental irrigation and 150 kg N ha^{-1} was the optimum combination for maximum grain yield of wheat.

In general soil nitrogen and water are two of the most important factors influencing, often interdependently, the growth of plants (Britto *et al.,* 2014) and therefore the objective of the present study was to examine the effect of water deficit and N fertilization levels on grain yield and some agronomic traits of barley (Cv. Karoun in Kavir) in Birjand, Iran.

MATERIALS AND METHODS

The study was carried out in research farm of Islamic Azad University located in 5 km of Birjand-Zahedan road (lat. 53°32' N., long. 59°13' E., alt. 1480 m.) in 2013. The mean precipitation, maximum temperature and minimum temperature are 176 mm, 41°C and -14°C in this region, respectively. Analysis of soil showed that the research farm had a soil with loam-sandy texture with pH of 7.86.

The experiment was a split plot design on the basis of a Randomized Complete Block Design with three replications. The main plot was devoted to irrigation treatment at four levels of full irrigation, irrigation withdrawal at flowering, irrigation withdrawal at grain-setting and irrigation withdrawal at flowering and grain-setting and the sub plot was devoted to N fertilization at four levels of 0, 75, 150 and 225 kg N ha^{-1} from urea source. The experimental plots were composed of 8 rows with the length of 3 m and an area of 6 m^2.

After farm selection, it was ploughed and was prepared by two vertical disking and field leveling. The grains of barley Cv. Karoun in Kavir (Nosrat) were disinfected with Benomel 5:1000. Then, they were sown by hand and were irrigated immediately. They were densely planted at the depth of 3-4 cm on ridges. N fertilizer from urea source was treated as heading at two stages of tillering on March 26, 2014 and spike appearance on April 13, 2014. The plots were manually weeded at three stages during growing season.

At physiological maturity, six plants were randomly selected in each plot taking margin effects into consideration and then, their morphological traits including plant height, number of leaves per main stem, spike length, and number of tillers per plant were measured. After the plants were harvested from an area of 2 m^2 from the middle of each plot on May 26 of 2014, the straw was separated from the grains and the grain yield was determined. The moisture of the cleaned grains of the plots was measured by NIR. The collected data were analyzed by MSTAT-C software package. The graphs were drawn by MS-Excel software package and the means were compared by Duncan Multi-range Test at 5% level.

RESULTS AND DISCUSSION

A. Plant height

Analysis of variance revealed that the effect of irrigation and its interaction with N fertilization was not significant for plant height, but N fertilization significantly influenced it at 1% level (Table 1).

Since barley is a determinate crop and its vegetative growth is terminated as soon as its reproductive growth starts, then the plant height increases before flowering due to the increased growth of stem internodes. Consequently, irrigation withdrawal at flowering and grain filling period had no significant effect on this trait (Table 2).

Means comparison showed that although N fertilization significantly increased plant height as compared to no N fertilization so that the treatment of 75, 150 and 225 kg N ha^{-1} resulted in 14.1, 20.23 and 24.64% higher plant height as compared to control, respectively, no statistically significant differences were observed between different levels of N fertilization (Table 3). In a study on wheat, Emam *et al.* (2009) reported that higher N levels resulted in higher plant height. Also, in a study on barley and triticale, Ghasemi (2012) showed that the application of 69 and 138 kg N ha^{-1} increased plant height by 25.3 and 13.6% as compared to no N application, respectively.

It seems that when N treatment is increased, its availability to plants is improved resulting in better growth of the plants and its higher height. N is a necessary element that plays an important role in plant biochemistry. It stimulates plant vegetative growth and leaf area when photosynthesis rate is increased and more phloem sap is produced. Then, plants become taller.

B. Number of leaves per main stem

According to analysis of variance, the effect of irrigation, N fertilization and their interaction was not significant for the number of leaves per main stem (Table 1). Means comparison of the effects of irrigation and N fertilization revealed that all irrigation and N fertilization levels were ranked in the same statistical level in terms of this trait (Tables 2 and 3).

Alizadeh *et al.* (2007) stated that drought stress would reduce the leaf area of the plants depending on the intensity and duration of the stress, but it seems that the final number of leaves would be less affected which is in agreement with our results. In other words, it can be said that the number of grains leaves per main stem is mainly influenced by genetic factors and less affected by the environment.

Table 1: Results of analysis of variance of morphological traits, grain moisture and grain yield of barley as affected by irrigation and N fertilization levels.

Sources of variation	df	Means of squares					
		Plant height	Leaf number per stem	Tiller number per plant	Spike length	Grain moisture (%)	Grain yield
Replication	2	364.79^{ns}	0.653^{ns}	0.276^{ns}	2.441^{ns}	1.489^{ns}	1026336.3^{ns}
Irrigation (A)	3	137.68^{ns}	0.723^{ns}	2.047^{ns}	0.445^{ns}	0.738^{ns}	3902585.2*
Error *a*	6	87.334	0.223	1.088	1.054	0.497	571694.93
Nitrogen (B)	3	400.98**	0.312^{ns}	1.332^{ns}	3.054**	0.403^{ns}	650296.66*
A × B	9	27.769^{ns}	0.353^{ns}	0.439^{ns}	0.13^{ns}	0.357^{ns}	710051.64**
Error *b*	24	24.243	0.292	1.426	0.285	0.364	209855.87
CV (%)	-	7.97	11.76	24.39	9.66	11.24	26.29

ns, * and ** show non-significance and significance at 5 and 1% level, respectively

Table 2: Means comparison for the effect of irrigation treatments on morphological traits, grain moisture and grain yield of barley.

Irrigation	Plant height (cm)	Leaf Number per main stem	Tiller number per plant	Spike length (cm)	Grain moisture (%)	Grain yield (kg ha^{-1})
Full irrigation	64.60a	4.44a	4.43a	5.27a	5.72a	2529 a
Irrigation withdrawal at flowering	57.23 a	4.69a	4.76a	5.49a	5.38a	1510b
Irrigation withdrawal at grain-setting	64.08 a	4.89a	4.97a	5.6 a	5.21a	1740ab
Irrigation withdrawal at both stages	61.08 a	4.35a	5.42a	5.69a	5.17a	1192b

Means with similar letter(s) in each column did not show significant differences

Table 3: Means comparison for the effect of N fertilization rate on Morphological traits, grain moisture and grain yield of barley.

Nitrogen rate (kg ha^{-1})	Plant height (cm)	Leaf number per main stem	Tiller number per plant	Grain moisture (%)	Grain yield (kg ha^{-1})
0	53.81 b	4.679 a	5.015 a	5.39 a	1568 b
75	61.40 a	4.472 a	5.236 a	5.11 a	1861 ab
150	64.70 a	4.445 a	4.445 a	4.46 a	2012 a
225	67.07 a	4.778 a	4.888 a	5.52 a	1529 b

Means with similar letter(s) in each column did not show significant differences.

C. Spike length

As analysis of variance showed, the irrigation and its interaction with N fertilization did not result in significant differences in spike length, but N levels significant affected it at 1% probability level (Table 1). In a study on barley, Tajali (2009) found that spike length exhibited no significant difference under drought stress and no stress conditions which is in agreement with our results.

Means comparison indicated that the application of 150 kg N ha^{-1} resulted in 19.9 and 8.9% higher spike length (5.9 cm) than N levels of 0 and 75 kg ha^{-1}, respectively, and although spike length under this treatment was 0.8% higher than that under the application of 225 kg N ha^{-1}, they were both ranked in the same statistical group (Fig. 1).

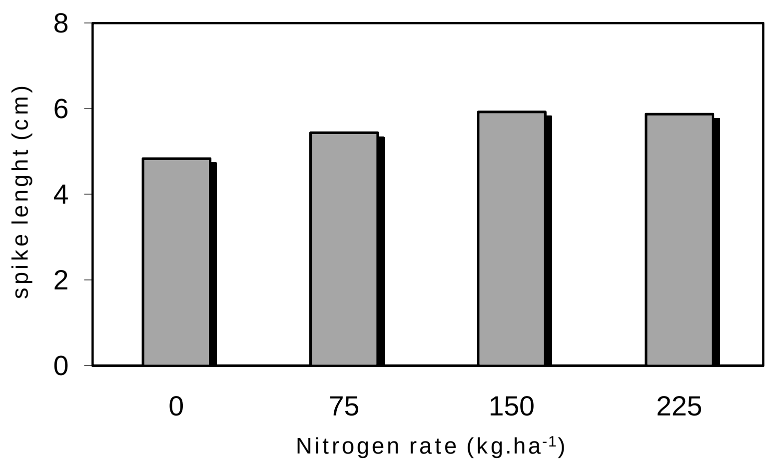

Fig. 1. Effect of nitrogen rate on spike lenght of barley.

In a study on spring barley, Seyedabadi (2010) found that the increase in N level from 50 to 100 kg ha^{-1} increased spike length by 12%, whereas further increase in N level up to 150 kg ha^{-1} increased it only by 6% which confirms our findings.

D. Number of tillers per plant

Analysis of variance revealed that the number of tillers per plant was not significantly affected by irrigation, N fertilization and their interaction (Table 1).

Number of tillers is a trait that is determined before stemming. So, irrigation withdrawal after this stage had no impact on this trait and all irrigation levels were ranked in the same statistical group in terms of this trait (Table 2).

Saeedi *et al.* (2010) showed that the effect of water withdrawal after spike-bearing was not significant on the number of tillers per plant of wheat. As well, means comparison indicated that different N levels were ranked in the same statistical group in terms of the number of tillers per plant (Table 3) which can be associated with the extra amount of N fertilization at different post-tillering fertilization treatments which only resulted in the preservation of the tillers that had been produced at vegetative phase rather than increasing their number.

Similarly, Ghasemi (2012) showed that the number of tillers per plant in barley and triticale was not influenced by different levels of irrigation and N fertilization and their interaction.

It seems that the appropriate feeding before or during tillers positively influenced the production of tillers and moderate rate of N fertilization at early or during tillering stimulated tillering while its treatment after tillering had no impact on increasing the number of tillers per plant.

E. Grain moisture percentage

According to the results of analysis of variance, grain moisture percentage was not significantly affected by irrigation, N fertilization and their interaction (Table 1). Means comparison for the simple effect of irrigation revealed that the highest and lower grain moisture percentage (5.717 and 5.175%) was obtained under full irrigation and irrigation withdrawal at flowering and grain-setting stages, respectively (Table 2).

N fertilization rate of 225 kg ha^{-1} also resulted in the highest grain moisture percentage of 5.525% as compared to other N rates (Table 3). However, all irrigation levels and all N levels were statistically ranked in the same group in terms of mean grain moisture percentage (Tables 2 and 3).

F. Grain yield

As analysis of variance revealed, the interaction between irrigation and N fertilization significantly influenced grain yield at 5% level and the interaction between irrigation and N fertilization was significant for it at 1% level (Table 1).

Means comparison revealed that irrigation withdrawal at flowering and grain-setting and at both flowering and grain-setting stages resulted in the loss of barley grain yield as compared to control by 40.3, 31.19 and 52.87%, respectively (Table 2).

Also, Behdad *et al.* (2009) showed that irrigation withdrawal at all growth stages reduced grain yield and that this loss was greater under irrigation withdrawal at flowering than at grain filling. It can be related to the fact that reproductive organs are formed at flowering stage and stress reduces grain number per spike and spike number per unit area resulted in final loss of yield. Bakhshi Khaniki *et al.* (2007) reported that irrigation withdrawal at flowering resulted in about 50% loss of grain yield of barley. In addition, Ezzat Ahmadi *et al.* (2011) stated that moisture stress not only limits source but also reduces sink and reserve capacity which naturally reduces shoot dry mater and grain yield significantly.

Means comparison of N levels indicated that the highest grain production potential of barley was obtained under N rate of 150 kg ha^{-1} which was 28.32, 8.11 and 31.59% higher than that under N rates of 0, 75 and 225 kg ha^{-1}, respectively (Table 2). The higher grain yield under N rate of 150 kg ha^{-1} can be related to the positive effect of N on grain yield components of barley. Anjum *et al.* (2009) showed that N application as budgeted immediately after irrigation produced the highest yield whose increase was caused by the increase in fertile tiller production and grain number per spike.

Alam *et al.* (2007), too, stated that higher N doses increased total bud number, number of fertile buds, total dry matter, 1000-grain weight, harvest index, and grain yield of barley.

Means comparison for the interaction between irrigation and N revealed that the highest grain yield (3037 kg ha^{-1}, on average) was produced under the treatment of full irrigation fertilized with 150 kg N ha^{-1} and the lowest one (560.2 kg ha^{-1}, on average) under the treatment of irrigation withdrawal at flowering and grain-setting stages with 225 kg N ha^{-1} (Fig. 2).

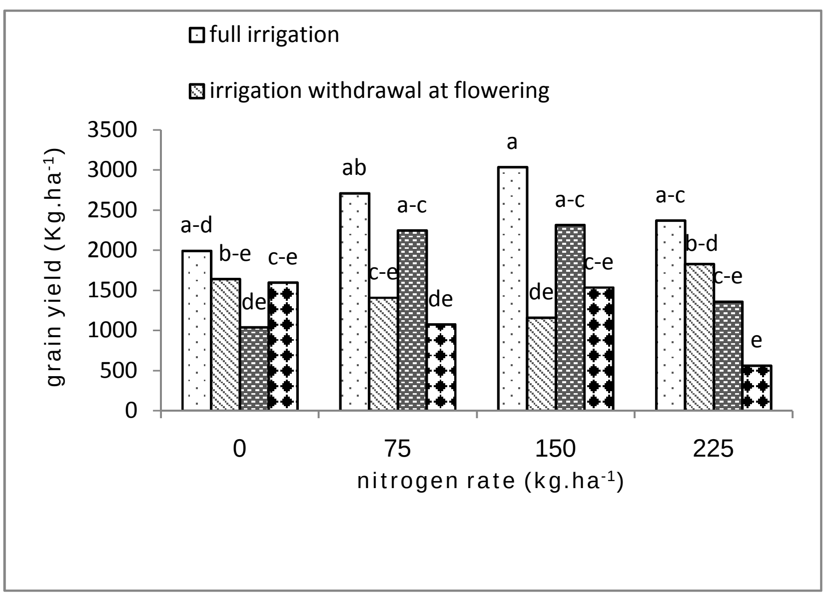

Fig. 2. Interaction of irrigation and nitrogen levels on grain yield of barley.

CONCLUSION

In total, it was found that water deficit stress at either flowering or grain-setting can significantly decrease grain yield due its inhibitory effect on reproductive growth and photosynthesis capacity. However, its occurrence at grain filling had less adverse effect than at flowering. The deficiency of nitrogen as one of the most necessary nutrients for plant can influence most vegetative and reproductive traits. Lower nitrogen fertilization rate significantly reduced such traits as grain yield, plant height and spike length of barley. According to the results, it is recommended to fertilize barley fields with 150 kg N ha^{-1} and to treat them with full irrigation in regions with climates similar to Birjand.

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