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Impact of foliar applied nitrogen on the growth and yield of barley (*Hordeum vulgare* L.) at local climate condition at Sindh

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Abstract

A field study was conducted at Students Farm, Sindh Agriculture University, Tandojam during Rabi, 2013-14 to investigate the growth and yield of barley under the influence of foliar spray of nitrogen. The local variety of barley was tested against seven treatments of foliar application of nitrogen viz. control, 1.0% nitrogen at tillering stage, 1.0% nitrogen at booting stage, 2.0% nitrogen at tillering stage, 2.0% nitrogen at booting stage, 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at tillering stage +2.0% nitrogen at booting stage. The analysis of variance showed that application of various treatments of foliar applied nitrogen exerted significant ($P<0.05$) positive effects on growth and yield parameters of barley as compared to control. The results suggested that foliar application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage resulted in maximum plant height (66.7cm), tillers (490.7m^{-2}), spike length (8.3cm), grains per spike (35.0), seed index:1000 seed weight (30.3g), biological yield (7116kg ha^{-1}) and grain yield (3077kg ha^{-1}). Hence, it is concluded from the results that foliar application of nitrogen at 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage along with recommended dose through soil proved best treatment for obtaining optimum yield (2972kg ha^{-1}) of barley because it showed non-significant ($p>0.05$) statistical differences with highest numerical yield (3077kg ha^{-1}) producing treatment 2.0% nitrogen at tillering stage +2.0% nitrogen at booting stage.

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Introduction

Barley (*Hordeum vulgare* L.) is the major cereal in many dry areas of the world and is vital for the livelihoods of many farmers. Barley is an annual cereal crop and grown in environments ranging from the desert of the Middle East to the high elevation of Himalayas (Hayes *et al.*, 2003). In Pakistan, it is mainly grown for grain and straw for small ruminants during winter, with green fodder sometimes used for winter grazing. Barley assumes fourth position in total cereal production in the world after wheat, rice, and maize. Barley is more productive under adverse environments than other cereals like wheat or sorghum.

Nitrogen is commonly the most limiting nutrient for crop production in the major world's agricultural areas and therefore adoption of good N management strategies often result in large economic benefits to farmers. Among the plant nutrients, nitrogen plays a very important role in crop productivity (Oikeh *et al.,* 2007). Nitrogen is the key element in achieving consistently high yields in cereals. Nitrogen is a constituent of many fundamental cell components such as nucleic acids, amino acids, enzymes, and photosynthetic pigments.

Foliar fertilization is a widely used practice to correct nutritional deficiencies in plants caused by improper supply of nutrient to roots (Ling and Silberbush, 2002). Woolfolk *et al.* (2002) reported that significant linear increase in total grain N was observed for post flowering foliar applications in five of six site-years Similarly, Roxana *et al.* (2003) observed that spike N content was higher in the N fertilized plants. Number of grains was positively associated with spike N and P content as well as spike dry matter at heading. Number of grains unit^{-1} of spike dry matter at heading in N fertilized micro crops tended to be higher than in N stressed ones.

One of the main causes of low yield of barley in Pakistan is improper fertilizer application which play crucial role in growth and yield. Under water deficit conditions, foliar fertilization is very useful to fulfill the plant nutrient requirements and immediately deliver nutrients to the tissues and organs of the crop (Ahmed *et al.*, 2011). Foliar fertilization of crops can complement and guarantee the availability of nutrients to crops for obtaining higher yields (Arif *et al.*, 2006).

Materials and methods

A field study was conducted at Students Farm, Sindh Agriculture University, Tandojam during Rabi, 2013-14 to investigate the growth and yield of barley under the influence of foliar spray of nitrogen. The experiment was laid out in a three replicated randomized complete block design (RCBD), having net plot size 4m x 3m (12m^2). The local variety of barley was tested against seven treatments of foliar application of nitrogen. The land was prepared by two dry plowings followed by precision land leveling. After soaking doze, when soil reached proper moisture level, two plowings with cultivator plow was done to achieve the fine seedbed. The seed of local variety of barley @ 125kg ha^{-1} was sown with single row hand drill on 30th November, 2013, maintaining distance of 22.5cm between rows. The recommended dose of NPK @ 120, 70 and 60kg ha^{-1} was applied in all the treatments in the form of Urea, DAP and SOP. Full dose of P and K, and half of N was applied at the time of sowing whereas, remaining half of N was applied at 1st irrigation. The treatments details are as under:

Treatments = 7

T_1 = No foliar application of nitrogen (control)

T_2 = 1.0% nitrogen at tillering stage

T_3 = 1.0% nitrogen at booting stage

T_4 = 2.0% nitrogen at tillering stage

T_5 = 2.0% nitrogen at booting stage

T_6 = 1.0% nitrogen at tillering stage+1.0% nitrogen at booting stage

T_7 = 2.0% nitrogen at tillering stage+2.0% nitrogen at booting stage

Observations recorded

1. Plant height (cm)
2. Tillers (m^2)
3. Spike length (cm)
4. Grains per spike
5. Seed index (1000-grain weight, g)

6. Biological yield (kg ha^{-1})
7. Grain yield (kg ha^{-1})

Procedure for recording observations

1. *Plant height:* Plant height was recorded in centimeters at maturity of crop using measurement tape from bottom to tip of the randomly selected plants in each plot and averaged.
2. *Tillers (m^2):* Total tiller for randomly selected plots m^{-2} were counted at the time of maturity and averaged.
3. *Spike length (cm):* Spike length was recorded in centimeters at maturity of crop using measurement tape from initiation to tip of the spike from randomly selected plant in each plot and averaged.
4. *Grains per spike:* The total number of grain in five randomly selected plants was counted in each plot and total number of grain was divided with total number of spikes.
5. *Seed index (1000-grain weight, g):* The seed index was calculated by taking 1000 grains from each plot separately in grams.
6. *Biological yield (kg ha^{-1}):* At maturity the crop in each plot was harvested and the total biomass was weighted. The biological yield per plot was converted to biological yield ha^{-1} in kilogram using following formula:

$$\text{Biological yield (kg ha}^{-1}\text{)} = \frac{\text{Biological yield plot}^{-1}\text{ (kg)}}{\text{Plot size (m}^2\text{)}} \times 100$$

7. *Grain yield (kg ha^{-1}):* At maturity the crop in each plot was harvested and threshed, and yield ha^{-1} was calculated by the following formula:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield plot}^{-1}\text{(kg)}}{\text{Plot size (m}^2\text{)}} \times 100$$

Statistical analysis

The collected data were subjected to ANOVA technique using Statistix 8.1 computer software (Statistix, 2006). The HSD test was applied to compare treatment means superiority, where necessary.

Experiment design = Randomized complete block design (RCBD)

Replications = 3

Plot size = 4m x 3m (12m^2)

Treatments = 7

T_1 = No foliar application of nitrogen (control)

T_2 = 1.0% nitrogen at tillering stage

T_3 = 1.0% nitrogen at booting stage

T_4 = 2.0% nitrogen at tillering stage

T_5 = 2.0% nitrogen at booting stage

T_6 = 1.0% nitrogen at tillering stage+1.0% nitrogen at booting stage

T_7 = 2.0% nitrogen at tillering stage+2.0% nitrogen at booting stage

Results

A field study was conducted at Students Farm, Sindh Agriculture University, Tandojam during Rabi, 2013-14 to investigate the growth and yield of barley under the influence of foliar spray of nitrogen. The experiment was laid out in a three replicated randomized complete block design (RCBD), having net plot size 4m x 3m (12m^2). The treatments comprised of: no foliar application of nitrogen (control), 1.0% nitrogen at tillering stage, 1.0% nitrogen at booting stage, 2.0% nitrogen at tillering stage, 2.0% nitrogen at booting stage, 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at tillering stage +2.0% nitrogen at booting stage. The observations were recorded on parameters of economic importance such as plant height (cm), tillers (m^2), spike length (cm), grains per spike, seed index (1000-grain weight, g), biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}).

Plant height (cm)

The data regarding plant height (cm) of barley as affected by foliarly applied different levels of nitrogen are presented in Table-1 and their analysis of variance as Appendix-I. The analysis of variance illustrated that the difference for plant height (cm) among various treatments was statistically significant ($P<0.05$).

The results revealed that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum plant height (66.7cm), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at tillering stage with 66.3 and 62.0cm plant height, respectively.

The plant height reduced to 60.0, 59.3 and 58.7cm when barley crop was sprayed with 1.0% nitrogen at tillering stage, 2.0% nitrogen at booting stage and 1.0% nitrogen at booting stage, respectively. However, minimum plant height (58.0cm) was recorded in No foliar application of nitrogen (control). The overall results suggested that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved economical treatment for achieving optimum plant height of barley.

Tillers (m^{-2})

The results pertaining to tillers (m^{-2}) of barley as affected by foliarly applied different levels of nitrogen are presented in Table-1 and their analysis of variance as Appendix-II. The analysis of variance indicated that the difference for tillers (m^{-2}) among various treatments was statistically non-significant ($P>0.05$).

The results suggested that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum tillers (490.7m^{-2}), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0 % nitrogen at tillering stage with 480.0 and 479.3 tillers m^{-2}, respectively. The number of tillers declined to 468.3, 446.7 and 443.3m^{-2} when barley crop was fertilized with 2.0% nitrogen at booting stage, 1.0% nitrogen at tillering stage and 1.0% nitrogen at booting stage, respectively. However, minimum number of tillers (441.7m^{-2}) was recorded in no foliar application of nitrogen (control). The overall results illustrated that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved appropriate treatment for obtaining optimum number of tillers m^{-2} of barley.

Spike length (cm)

The results with regard to spike length (cm) of barley as affected by foliarly applied different levels of nitrogen are presented in Table-1 and their analysis of variance as Appendix-III. The analysis of variance showed that the difference for spike length (cm) among various treatments was statistically significant ($P<0.05$).

The results suggested that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum spike length (8.3cm), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at booting stage with 8.0 and 6.7cm spike length, respectively. The spike length diminished to 6.3, 6.0 and 5.7cm when barley crop was fertilized with 2.0 % nitrogen at tillering stage, 1.0% nitrogen at booting stage and 1.0% nitrogen at tillering stage, respectively. However, minimum spike length (5.3cm) was recorded in No foliar application of nitrogen (control). The overall results showed that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved suitable treatment for attaining ideal spike length of barley.

Table 1. Influence of foliar applied nitrogen on plant growth parameter of barley.

Treatments	Plant height (cm)	Tillers (m^{-2})	Spike length (cm)
T_1 = No foliar application of nitrogen (control)	58.0 C	441.7	5.3 C
T_2 = 1.0% nitrogen at tillering stage	60.0 BC	446.7	5.7 C
T_3 = 1.0% nitrogen at booting stage	58.7 C	443.3	6.0 C
T_4 = 2.0% nitrogen at tillering stage	62.0 B	479.3	6.3 C
T_5 = 2.0% nitrogen at booting stage	59.3 BC	468.3	6.7 BC
T_6 = 1.0% nitrogen at tillering stage+1.0% nitrogen at booting stage	66.3 A	480.0	8.0 AB
T_7 = 2.0% nitrogen at tillering stage+2.0% nitrogen at booting stage	66.7 A	490.7	8.3 A

Grains per spike

The results pertaining to grains per spike of barley as affected by foliarly applied different levels of nitrogen are presented in Table-2 and their analysis of variance as Appendix-IV. The analysis of variance demonstrated that the difference for grains per spike among various treatments was statistically significant ($P<0.05$).

The data displayed that application of 2.0 % nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum grains per spike (35.0), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at booting stage with 34.7 and 32.0 grains per spike, respectively.

The grains per spike decreased to 31.3, 30.7 and 30.3 when barley crop was fertilized with 02.0% nitrogen at tillering stage, 1.0% nitrogen at booting stage and 1.0% nitrogen at tillering stage, respectively. However, minimum grains per spike (29.7) were noted in no foliar application of nitrogen (control). The overall results suggested that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved most reasonable treatment for obtaining optimum number of grains per spike of barley.

Seed index (1000-grain weight, g)

The results pertaining to seed index (1000-grain weight, g) of barley as affected by foliarly applied different levels of nitrogen are presented in Table-2 and their analysis of variance as Appendix-V. The analysis of variance indicated that the difference for seed index among various treatments was statistically significant ($P<0.05$).

The results suggested that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum seed index (30.3g), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at booting stage with 29.7 and 28.0g seed index, respectively.

The seed index reduced to 27.7, 27.3 and 27.0g when barley crop was fertilized with 02.0% nitrogen at tillering stage, 1.0% nitrogen at booting stage and 1.0% nitrogen at tillering stage, respectively. However, minimum seed index (26.3 g) was noted in no foliar application of nitrogen (control).

The overall results illustrated that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved appropriate treatment for obtaining optimum seed index of barley.

Table 2. Influence of foliar applied nitrogen on grain yield parameters of barley.

Treatments	Grain per spike	Seed index (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})
No foliar application of nitrogen (control)	29.7 B	26.3 C	6167 D	2703 D
1.0% nitrogen at tillering stage	30.3 B	27.0 C	6499 BD	2797 CD
1.0% nitrogen at booting stage	30.7 B	27.3 C	6250 CD	2811 CD
2.0% nitrogen at tillering stage	31.3 B	27.7 C	6796 AC	2830 CD
2.0% nitrogen at booting stage	32.0 AB	28.0 BC	6771 AD	2867 BC
1.0% nitrogen at tillering stage+1.0% nitrogen at booting stage	34.7 A	29.7 AB	7015 AB	2972 AB
2.0% nitrogen at tillering stage+2.0% nitrogen at booting stage	35.0 A	30.3 A	7116 A	3077 A

Biological yield (kg ha^{-1})

The results pertaining to biological yield (kg ha^{-1}) of barley as affected by foliarly applied different levels of nitrogen are presented in Table-2 and their analysis of variance as Appendix-VI. The analysis of variance suggested that the difference for biological yield among various treatments was statistically significant ($P<0.05$).

The results indicated that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage produced maximum biological yield (7116kg ha^{-1}), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at tillering stage with 7015 and 6796kg ha^{-1} biological yield, respectively.

The biological yield diminished to 6771, 6499 and 6250kg ha^{-1} when barley crop was fertilized with 2.0% nitrogen at booting stage, 1.0% nitrogen at tillering stage and 1.0% nitrogen at booting stage, respectively. However, minimum biological yield (6167kg ha^{-1}) was registered in no foliar application of nitrogen (control). The overall results showed that foliar application of 1.0% nitrogen at tillering stage+1.0% nitrogen at booting stage in addition to usual application through soil proved most suitable treatment for gaining optimal biological yield of barley.

Grain yield (kg ha^{-1})

The data regarding grain yield (kg ha^{-1}) of barley as affected by foliarly applied different levels of nitrogen are presented in Table 2 and their analysis of variance as Appendix-VII.

The analysis of variance indicated that the difference for grain yield among various treatments was statistically significant (P<0.05).

The results revealed that application of 2.0% nitrogen at tillering stage + 2.0% nitrogen at booting stage resulted in maximum grain yield (3077 kg ha^{-1}), followed by 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage and 2.0% nitrogen at booting stage with 2972 and 2867kg ha^{-1} grain yield, respectively. The grain yield declined to 2830, 2811 and 2797kg ha^{-1} when barley crop was fertilized with 02.0% nitrogen at tillering stage, 1.0% nitrogen at booting stage and 1.0% nitrogen at tillering stage, respectively. However, minimum grain yield (2703kg ha^{-1}) was recorded in No foliar application of nitrogen (control). The overall results suggested that foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage in addition to usual application through soil proved appropriate treatment for obtaining optimum grain yield of barley.

Discussion

The findings of this study showed that foliar applied different concentrations of nitrogen significantly (P<0.05) affected the effect the growth and grain yield of barley as compared to no foliar application of nitrogen (control). Spraying barley plants with 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage increased growth and yield contributing characteristics i.e. plant height, tillers, and spike length, grains per spike, seed index, biological yield and grain yield. This may be due to the stimulating effect of nitrogen through improving the physiological performance of plants and multiple advantage of foliar application method such as rapid and efficient response to plant needs, less product needed and independence of soil conditions. Similar results were observed by Arif *et al.*, 2006 who reported that utilization of urea applied through soil is not as effective as when it is supplied to the plant through foliage along with soil application. The significant increase in the spikes per plant recorded could be attributed to better growth and development attained by the crop due to additional application of nitrogen, known to be involved in photosynthesis, protein metabolism and energy transfer reactions.

Singh *et al.* (1995) reported significant improvement in the effective tillers per plant with nitrogen application up to 120kg ha^{-1}. The higher nitrogen nutrition to the crop increased the vegetative growth by better photosynthesis through higher leaf area thereby resulting in better translocation of photosynthesis from source to sink. This could be attributed to the fact that nitrogen helped to produce better vegetative growth as a result of which photosynthetic area increased thereby more food material synthesized contributed to the improvement in grains per spike. The results are supported by Beena *et al.* (2013) who reported that barley grain and straw yields were significantly increased by the integral application of urea through broadcasting and foliar spray over soil application alone. Concerning the effect of nutrients foliar spray on the aforementioned parameters studied in this experiments, the positive marked increases could be due to maintain balanced plant physiology as mentioned in several research studies on their reaction and disturbances caused by their deficiency (Malakouti, 2008). In line of these results Wade *et al.* (2012) also reported that the efficiency of foliar feeding is higher than of soil fertilization, one reason is because of the supply of the required nutrient goes directly to the location of the high demand in the leaves and its relatively quick absorption. They stated that the time of 50% absorption of nitrogen as urea is 1/2 -2 hours. It is also noticed that Foliar feeding of nutrient may actually promote root absorption of the same nutrient, similar results were obtained by Woolfolk *et al.* (2002). These results are in concurrence with the findings of Amal *et al.* (2011) who suggested that foliar feeding with urea @ 2% produced the highest significant values for plant height, number of spikes m^2, spike weight m^2, as well as grain, straw and biological yields $unit^{-1}$ area. Correspondingly, Yaseen *et al.* (2010) indicated that nitrogen foliar spray (1% urea) gave significant increase in 1000-grain weight, nitrogen concentration and uptake in both grain and straw and protein yield as compared with the control. Results also revealed that spraying wheat plant with 1% urea showed marked increment in micronutrients concentration and uptake.

The results are also in line with the findings of Ali *et al.* (2009) who reported that foliar application of boron at tillering and/or booting and milking growth stage(s) increased the grain yield of wheat. In another study, Muhammad *et al.* (2011) suggested that foliar spray of nitrogen at tillering and /or booting and milking stage increased the grain yield of wheat. Similarly, Shah *et al.* (2003) explored that foliar-applied urea (2, 4 and 6%) was better utilized by the wheat plants compared to the standard soil application. Irrespective of growth stages, foliage efficacy of urea was most prominent at 4% solution. The results are also in harmony with Khan *et al.* (2009) who revealed that foliar application of urea significantly increased plant height, spike length, number of grains per spike, 100-grain weight, biological yield, grain yield and N uptake by the crop. Different nitrogen levels increased the nutrient content in the plants that lead to increase in vegetative growth. Besides, nitrogen is an involved in cell division and cell elongation. The increase in vegetative growth is evident from the plant height, tiller production and dry matter accumulation and the increase in different yield contributing characters *viz.,* spikes per plant, spike length, grains per spike thereby consequently improving the straw and grain yield of crop. The increase in grain and straw yield with application of nitrogen has also been reported by Akthar (2001). There are potential benefits of providing N to cereals via foliage as urea solutions. Among these benefits are reduced nitrogen losses through denitrification and leaching when root capacity for absorption is impaired by low soil moisture or saline soil conditions. Foliar application of dilute urea solutions have been preferred over soil applications under root stress conditions for supplying N to wheat. Concentrations of up to 30% of urea can be used safely when applied with low volume sprayers (Abbasdokht and Marvi, 2006). Foliar feeding technique, as a particular way to supply these nutrients could avoid these factors and results in rapid absorption. Foliar feeding of micronutrients generally is more effective and less costly. It is well known that soil application of NPK fertilizers may lead to some losses of these fertilizers.

However, application of such macronutrients as foliar spray may decrease such losses (Beena *et al.*, 2013). This procedure can also improve nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil (Emam and Borjian, 2000). On the other hand, foliar feeding of a nutrient may actually promote root absorption of the same nutrient or other nutrients through improving root growth and increasing nutrients uptake (Gul *et al.*, 2011).

Conclusions

It is concluded from the results that all the nitrogen foliar application levels exerted significant positive effects on growth and yield traits of barley. Foliar application of 1.0% nitrogen at tillering stage +1.0% nitrogen at booting stage produced at par results with foliar application of 2.0% nitrogen at tillering stage +2.0% nitrogen at booting and proved best treatment for obtaining optimum yield of barley.

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