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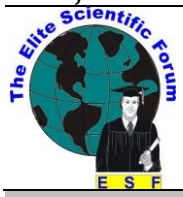

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RESEARCH ARTICLE

Effect of Foliar Application of Nitrogen and Boron on Growth, Yield and Quality of Wheat (*Triticum aestivum* L.)

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ABSTRACT

The deficiency of nitrogen (N) and boron (B) is increasing among the cereal crops that reduces yield and nutritional value of grains. Foliar spray is a possible option to maximize uptake of nutrients which enhances the productivity of wheat. A field experiment was conducted to determine the effect of foliar application of nitrogen and boron on growth, yield and quality of wheat at Agronomic Research Farm, University of Agriculture, Faisalabad during Rabi season 2017-18. Crop was sown by hand drill in plots with net size 5.0 m × 1.8 m. The experiment was consisted of 16 treatments in RCBD factorial design with two factors which was replicated three times. Factor A consisted of four levels of nitrogen (N_0 control = 0%, N_1 = 4%, N_2= 8% and N_3 = 12%) and Factor B consisted of four levels of boron (B_0 control = 0%, B_1 = 1%, B_2 = 2% and B_3 = 3%). The sources for nitrogen and boron were urea and boric acid which contains 46% nitrogen and 17% boron, respectively. Significantly the maximum spike length (17.15 cm), grains spike^{-1} (57.41), 1000 grain weight (36.15 g), grain yield (5.47 t ha^{-1}), biological yield (14.42 t ha^{-1}), harvest index (37.98m%), proteins (12.90 %) and carbohydrates (69.02 %) were noticed when 8 % foliar spray of nitrogen at tillering stage and 2 % boron at booting stage was applied. It is recommended from observations that 8 % foliar spray of nitrogen at tillering stage and 2 % boron at booting stage is helpful for achieving higher economic yield of wheat. It was concluded from the research that application of nitrogen and boron at a certain level can effectively enhance crop productivity as well as economic returns.

INTRODUCTION

Wheat is the main crop of Pakistan, so, most of the agricultural land is dedicated to this crop and the production of the crop is much more than that of other crops. It is the staple food of the country and have prime importance in terms of nutritive value, trade, consumption, storage quality, adaptability and production. About 45% of nutrition of people in Pakistan is met by wheat (Rizwan et al., 2017). Wheat is grown worldwide in numerous countries and various climatic conditions (Aghanejad et al., 2015). Wheat is a cereal crop which contains minerals, protein and carbohydrates (Habib, 2009). It provides 20% of daily protein, calories and contributes in the diet nearly 70 to 72% (Habbasha et al., 2013). Main causes which decrease the yield of wheat are non-judicious utilization of fertilizers such as nitrogen at right time, no or lesser use of micronutrients such as boron and zinc, late sowing, shortage of water and more weed infestations (Nadim et al., 2011). In future, when the population of the world will be increased, the yield of present wheat may be low to overcome the requirement of food, so, it is necessary to rise the production of wheat and to protect it from different stresses (Chatrath et al., 2007). Macro and micronutrients both are important in agriculture sector and have a great role in vegetative improvement and yield of wheat crop. In Pakistan, soil application of fertilizer is common method but mostly nutrients are leached into soil and are not completely available to plants (Eichert and Burkhardt, 2001). Wheat yield can be enhanced by various factors including macronutrients and micronutrients either as a means of soil application or foliar use. The foliar application has been proved to be the more efficient when compared with soil application due to active

absorption by plant leaves and minimum cost per unit area. Nitrogenous fertilizers play vital role in production and quality of wheat (Wilhelm et al., 2002). The nitrogen fertilizer which is applied directly to the soil is utilized only 20-50% by crops (Veesar et al., 2017) and rest of nitrogen is lost through denitrification and leaching, therefore, some struggles are required to reduce these losses. Foliar spray of nitrogen is a successful method which increases the accessibility of nitrogen to crop. Foliar applications of nitrogen have increased grain yield, especially when applied at tillering stage (Veesar et al., 2017; Babar et al., 2011; Gooding et al., 2007). Foliar spray of nitrogen is also very beneficial to get more growth and higher yield (Bameri et al., 2012; Nadim et al., 2012; Zhao et al., 2011; Sajid et al., 2008).

Boron also plays important role in plant pollen tube growth, cell division, leaf expansion, formation of cell wall, cell elongation, membrane integrity, water relations of plant, ionic absorption and all these processes might be affected due to shortage of boron (Gupta and Solanki, 2013). Foliar application of boron is the most productive when roots of plants are unable to absorb boron from soil due to the physical and chemical properties of soil such as calcium carbonate, pH, soil texture, cultivation, soil temperature, microbial action, organic matter and leaching losses (Jalilian et al., 2016; Babaeian et al., 2011; Cakmak, 2008). Boron as a foliar spray at early stage can't give better result as better at booting stage of crop (Tahir et al., 2009). Boron as a foliar spray improved the grain size, number and yield (Habib, 2009). It has been seen that the leaves of the plant were more efficient in nutrient uptake through leaves as compared to uptake by roots through soil (Ali, 2012). The research points out the role of N and B on growth, yield and grain quality of wheat. Objectives of the study were to evaluate the optimum amount of foliar applied N and B at tillering and booting stages, respectively, to achieve high economic yield and good quality of wheat crop.

MATERIALS AND METHODS

Research trial was conducted during Rabi season 2017-18 at University of Agriculture, Faisalabad, Pakistan. Soil was analyzed for its chemical and physical properties. Hydrometer method was used to determine the texture of soil which was sandy loam. Whole field was flood irrigated one week before the plantation of crop. The data recorded for soil parameters is provided in table 3. Basal dose of NPK was used while the preparation the experimental field. Complete dose of P and K was applied before sowing while the N was applied in splits. The wheat variety "Ujhala-2016" was sown as research crop in last week of the November 2017 having seed rate of 125 kg ha^{-1}. Seed rate 125 kg/ha was used, and the crop was sown using hand drill in equal line to line distance. Treatments were different levels of foliar spray of nitrogen (Urea Source) N_0 = 0% N (Control), N_1 = 4% N, N_2= 8% N, N_3 = 12% N at tillering stage and Boron Spray (Boric acid Source) B_0 = 0% B (Control), B_1 = 1% B, B_2 = 2% B, B_3 = 3% B at booting stage. Total four irrigations were applied to crop. Preventive and curative measures were adopted for less weed infestation, diseases and insects' control. All agronomic practices were same for each experimental plot. Crop was harvested at full maturity and threshed after sun-drying. Recorded data was analyzed statistically at 5 % probability level and compared the difference among the means of treatment (Steel et al., 1997).

RESULTS AND DISCUSSION

Plant height (cm)

Data recorded is presented in table 1 Data showed that plant height was significantly affected by foliar spray of N and B. Results indicated that maximum plant height (118.47 cm) was obtained in treatment N_2B_2 where foliar spray of 8% nitrogen at tillering and 2% boron at booting stage was applied and difference was statistically significant as compared to other treatment groups. However, the minimum plant height (81.07 cm) was obtained by N_0B_0 where no spray of N and B was applied. This increase plant height might be owing to role played by nitrogen and boron in cell wall formation which aided to increased plant height. Results of this study are supported by Bameri et al. (2012) as they reported chlorophyll and Indole-acetic acid (IAA) formation were increased with the spray of boron which improved the height of plant. Veesar et al. (2017) also observed increase in plant height with foliar spray of nitrogen.

Number of productive tillers (m^{-2})

Productive tillers (m^{-2}) have great impact on grain yield and straw yield in case of wheat (Table 1). Results revealed that significantly the maximum productive tillers (376 m^{-2}) were counted in treatment N_2B_2 where 8% N at tillering stage and 2% boron at booting stage was sprayed. However, significantly, the minimum productive tillers (310 m^{-2}) were noted in treatment N_0B_0 where foliar spray of N and B was not applied. Foliar spray of N and B considerably increased the fertile tillers in wheat crop. These results are conformed by Veesar et al. (2017) who have also observed increased productive tillers with urea spray. Huang et al. (2000) concluded that B deficiency in cereals may result in reduced number of fertile tillers $plant^{-1}$. Rehman et al. (2012) have documented that foliar applied B significantly increased productive tillers $plant^{-1}$ of wheat.

Spike length (cm)

Spike length of wheat was positively influenced with the foliar spray of N and B (Table 1). Results indicated

Table 1: Effect of Foliar Application of Nitrogen and Boron on growth, yield and quality of Wheat (*Triticum aestivum* L.)

Treatments	Plant height (cm)	Productive Tillers (m^{-2})	Spike length (cm)	Grains spike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})
N_0 = 0%	84.28^{D}	314.75^{D}	15.49^{D}	46.26^{D}	28.87^{D}	4.03^{D}
N_1 = 4%	102.86^{B}	351.83^{B}	15.68^{B}	51.46^{B}	32.70^{B}	4.76^{B}
N_2 = 8%	111.96^{A}	366.92^{A}	16.54^{A}	55.10^{A}	34.75^{A}	5.18^{A}
N_3 =12%	94.82^{C}	341.42^{C}	15.08^{C}	50.79^{C}	30.80^{C}	4.48^{C}
LSD=0.5%	2.040	1.492	0.202	0.496	0.130	0.029
B_0 = 0%	91.12^{D}	330.83^{D}	14.26^{D}	48.43^{D}	30.13^{D}	4.28^{D}
B_1 = 1%	100.77^{B}	345.00^{C}	15.27^{C}	51.21^{C}	32.29^{B}	4.70^{B}
B_2 = 2%	103.57^{A}	352.00^{A}	15.73^{A}	52.24^{A}	32.86^{A}	4.83^{A}
B_3 = 3%	98.45^{C}	347.08^{B}	15.52^{B}	51.73^{B}	31.84^{C}	4.65^{C}
LSD=0.5%	2.040	1.492	0.202	0.496	0.130	0.029
$N_0 \times B_0$	81.07^{l}	310.00^{p}	12.81^{n}	44.02^{l}	28.38^{p}	3.87^{p}
$N_0 \times B_1$	83.95^{kl}	313.00^{o}	13.23^{m}	45.14^{k}	28.67^{o}	3.96^{o}
$N_0 \times B_2$	87.14^{jk}	320.00^{m}	13.62^{lm}	46.50^{j}	29.44^{m}	4.06^{n}
$N_0 \times B_3$	84.95^{kl}	316.00^{n}	14.31^{jk}	49.37^{h}	29.01^{n}	4.21^{l}
$N_1 \times B_0$	89.62^{ij}	327.67^{l}	13.96^{kl}	47.85^{i}	29.94^{l}	4.15^{m}
$N_1 \times B_1$	107.9^{cd}	360.00e	15.90^{ef}	52.52^{de}	33.66^{e}	4.98^{e}
$N_1 \times B_2$	109.76^{c}	363.00^{d}	16.69^{bc}	53.47^{d}	34.54^{d}	5.10^{d}
$N_1 \times B_3$	104.14^{de}	356.67f	16.14^{de}	52.00^{e}	32.67^{f}	4.82^{f}
$N_2 \times B_0$	102.19^{ef}	353.00^{g}	15.62fg	51.80^{ef}	31.99^{g}	4.76^{g}
$N_2 \times B_1$	115.52^{ab}	367.33^{c}	16.97^{ab}	56.19^{b}	35.76^{b}	5.30^{b}
$N_2 \times B_2$	118.47^{a}	376.00^{a}	17.15^{a}	57.4^{a}	36.15^{a}	5.47^{a}
$N_2 \times B_3$	111.66^{bc}	371.33^{b}	16.42^{cd}	54.99^{c}	35.09^{c}	5.18^{c}
$N_3 \times B_0$	91.62^{i}	332.67^{k}	14.66^{ij}	50.04^{gh}	30.23^{k}	4.43^{k}
$N_3 \times B_1$	95.71^{gh}	339.67^{j}	14.98^{hi}	50.98^{fg}	31.05^{i}	4.54^{i}
$N_3 \times B_2$	89.90^{fg}	349.00^{h}	15.46^{g}	51.58^{ef}	31.32^{h}	4.66^{h}
$N_3 \times B_3$	93.04^{hi}	344.33^{i}	15.23^{gh}	50.56^{g}	30.60^{j}	4.40^{j}
LSD=0.5%	4.081	2.984	0.404	0.992	0.260	0.059

In a column, the values with same letter or without letters do not differ significantly.

Table 2: Effect of Foliar Application of Nitrogen and Boron on growth, yield and quality of Wheat (*Triticum aestivum* L.)

Treatments	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)	Protein Content (%)	Carbohydrates (%)
N0= 0%	12.32^{D}	8.24^{D}	32.67^{D}	9.60^{D}	64.72^{D}
N1= 4%	13.45^{B}	8.60^{B}	35.36^{B}	11.42^{B}	67.05^{B}
N2= 8%	14.02^{A}	8.79^{A}	36.90^{A}	12.35^{A}	68.27^{A}
N3=12%	13.12^{C}	8.51^{C}	34.19^{C}	10.97^{C}	66.17^{C}
LSD=0.5%	0.077	0.075	0.272	0.094	0.124
B0= 0%	12.73^{D}	8.36^{C}	33.57^{D}	10.27^{D}	65.50^{D}
B1= 1%	13.38^{B}	8.59^{AB}	35.03^{B}	11.22^{C}	66.80^{B}
B2= 2%	13.52^{A}	8.64^{A}	35.60^{A}	11.52^{A}	67.15^{A}
B3= 3%	13.29^{C}	8.56^{B}	34.94^{C}	11.32^{B}	66.67^{C}
LSD=0.5%	0.077	0.075	0.272	0.094	0.124
N0×B0	12.14^{m}	8.14^{l}	31.88^{k}	9.00^{p}	64.20^{p}
N0×B1	12.22^{lm}	8.20^{kl}	32.44^{j}	9.30^{o}	64.50^{o}
N0×B2	12.36^{kl}	8.27^{jkl}	32.88^{ij}	9.80^{n}	64.80^{n}
N0×B3	12.58^{j}	8.36^{ij}	33.49^{h}	10.30^{l}	65.40^{l}
N1×B0	12.48^{jk}	8.34^{ijk}	33.27^{hi}	10.00^{m}	65.10^{m}
N1×B1	13.80^{d}	8.70^{cde}	36.06^{d}	11.90^{e}	67.70^{e}
N1×B2	13.93^{cd}	8.73^{cd}	36.64^{c}	12.10^{d}	68.10^{d}
N1×B3	13.59^{e}	8.63^{cdef}	35.48^{e}	11.70^{f}	67.30^{f}
N2×B0	13.46^{ef}	8.54^{fgh}	35.35^{ef}	11.50^{g}	67.02^{g}
N2×B1	14.21^{b}	8.89^{ab}	37.30^{b}	12.60^{b}	68.70^{b}
N2×B2	14.42^{a}	8.97^{a}	37.98^{a}	12.90^{a}	69.02^{a}
N2×B3	14.00^{c}	8.78^{bc}	36.99^{bc}	12.40^{c}	68.40^{c}
N3×B0	12.84^{i}	8.42^{hi}	33.78^{gh}	10.60^{k}	65.70^{k}
N3×B1	13.26^{g}	8.56^{efgh}	34.26^{g}	11.10^{i}	66.3^{i}
N3×B2	13.37^{fg}	8.59^{defg}	34.89^{f}	11.30^{h}	66.70^{h}
N3×B3	13.00^{h}	8.46^{ghi}	33.81^{gh}	10.90^{j}	66.01^{j}
LSD=0.5%	0.154	0.150	0.544	0.189	0.248

In a column, the values with same letter or without letters do not differ significantly

Table 3: Analysis of experimental soil

Component	Unit	Value
pH	-	7.9
Electrical conductivity (EC)	dS m^{-1}	2.1
Organic matter (O.M)	%	0.80
Total Nitrogen (T.N)	%	0.04
Phosphorus (P)	mg/kg	4.34
Potassium (K)	mg/kg	141
Zinc (Zn)	mg/kg	0.79
Boron (B)	mg/kg	0.41
Sand	%	46
Silt	%	38
Clay	%	16

that significantly the maximum spike length (17.15cm) was noted from treatment N_2B_2 where foliar spray of nitrogen at the rate of 8% at tillering stage and boron at the rate of 2% at booting stage were applied. However, significantly, the minimum spike length (12.81 cm) was obtained by treatment N_0B_0 (control) where foliar spray of N and B was not applied at any stage. Saeed et al. (2012) also documented that foliar spray of urea at tillering stage significantly affected spike length in a positive way. Rehman et al. (2012) also stated that spike length was improved with the foliar spray of boron.

Grains spike^{-1}

Nitrogen and boron foliar spray significantly enhanced the grain number in spike. Data recorded is presented in table 1. Significantly the maximum grains spike^{-1} (57.41) were counted in treatment N_2B_2 where foliar spray of N at the rate of 8% at tillering stage and B at the rate of 2% at booting stage was applied. However, significantly the minimum grains spike^{-1} (44.02) were obtained by treatment N_0B_0 where foliar spray of nitrogen and boron was not applied. Nitrogen is helpful in cell division and cell development. This function of nitrogen may be a reason of increased grains spike^{-1} as Barbottin et al. (2005) reported that it also played role in grain formation. These findings are in alliance with Rahman et al. (2014) who found better crop responses with N spray as foliar spray. B also plays a significant role in grain setting. Current outcomes are in support of findings reported by Tahir et al. (2009) who stated that grain spike^{-1} improved efficiently by the foliar spray of B.

1000-grain weight (g)

The recorded data (table 1) directed that foliar spray of N at tillering stage and B at booting stage had significant influence on 1000-grain weight in wheat. Statistically the maximum 1000-grain weight (36.15 g) was achieved from the treatment N_2B_2 where foliar spray of N at the rate of 8% at tillering stage and B at the rate of 2% at booting stage was applied. Significantly, the minimum 1000-grain weight (28.38 g) was found in treatment N_0B_0 where spray of N and B was not applied at any stage. Results of the current research are consistent with those reported by Yaseen et al. (2010) who indicated that urea and micronutrients as a foliar spray significantly improved 1000-grain weight. Torun et al. (2001) also concluded that 1000-grain weight was significantly improved with B sprayed.

Grain yield (t ha^{-1})

Data recorded is presented in table 1. The recorded data directed that foliar spray of N at tillering stage and B at booting stage had significant influence on grain yield in wheat. Statistically, the maximum grain yield (5.47 t ha^{-1}) was achieved from treatment N_2B_2 where foliar spray of N at the rate of 8% at tillering stage and B at the rate of 2% at booting stage was sprayed. However, significantly, the lowest yield (3.87 t ha^{-1}) was recorded from the treatment N_0B_0 where no foliar spray of N and B was applied. These outcomes are proved by Yaseen et al. (2010) who stated that foliar spray of urea and micro-nutrients increased wheat grain yield up to 24-38% in comparison to control. These results are also in line with Chaudry et al. (2007) who reported that B spray along with basal dose of NPK significantly improved the wheat produce.

Biological yield (t ha^{-1})

The data recorded (table 2) revealed the significant effects of nitrogen and boron on biological yield of wheat. Treatment N_2B_2 where 8% N at tillering stage and 2% B at booting stage were sprayed resulted significantly in the higher biological yield (14.42 t ha^{-1}), while, in treatment (N_0B_0) where N and B was not sprayed, produced the lowest yield (12.14 t ha^{-1}). Foliar spray can balance and give assurance of availability of nutrients for gaining higher yields (Arif et al., 2006). These finding are correlated to Wagan et al. (2017) who confirmed that foliar applied urea resulted in noteworthy rise in yield of wheat. These findings agree with Farooq et al. (2012) who stated that higher yield of wheat obtained with boron spray.

Straw yield (t ha^{-1})

The recorded data (table 2) revealed that spray of N and B have substantial effects on straw yield. Significantly the maximum straw yield was (8.97 t ha^{-1}) recorded in N_2B_2 where foliar spray of N at the rate of 8% at tillering stage and B at the rate of 2% at booting stage were sprayed. However, significantly minimum straw yield (8.14 t ha^{-1}) was achieved by N_0B_0 where no N and B was sprayed. These outcomes are also confirmed by Yaseen et al. (2010) as they indicated that foliar applied urea and micronutrients increased straw yield of wheat. Fakir et al. (2016) also stated that foliar spray of boron at booting stage enhanced straw yield.

Harvest index (%)

The data concerning about H.I is provided in table 2 which depicts that foliar sprays of N and B revealed that these both have remarkable effects on H.I. Significantly the highest H.I (37.98%) was recorded from the treatment N_2B_2 where nitrogen at the rate of 8% at tillering stage and boron at the rate of 2% at

booting stage were sprayed. However, significantly minimum harvest index (31.88%) was obtained by treatment N_0B_0 where spray of N and B was not applied. These findings are supported by Khan et al. (2005) as they determined that both N and B have significant effects on harvest index of wheat.

Protein content (%)

Data recorded is presented in table 2. Foliar spray of nitrogen and boron showed a direct and positive relation to grain protein contents. Statistically, the maximum proteins (12.90%) were calculated with treatment N_2B_2 where 8% nitrogen at tillering stage and 2 % boron was sprayed at booting stage. However, significantly minimum protein contents (9.00%) were obtained by treatment N_0B_0 where no spray of N and B was applied. These findings are scientifically supported by Tea et al. (2007) as they reported increased assimilate deposition and improved proteins with foliar applied N. Ali et al. (2009) conducted research on use of boron and concluded from their results that boron spray effectively enhanced protein content in grains.

Carbohydrates content (%)

Data recorded is presented in table 2 which revealed that foliar spray of N and B have substantial effects on carbohydrate contents. Significantly the highest carbohydrate contents (69.02%) were calculated with the treatment N_2B_2 where 8% nitrogen at tillering stage and 2 % boron was sprayed at booting stage. However, significantly minimum carbohydrate concentration (64.20%) was found in treatment N_0B_0 where spray of N and B was not applied at any stage. Increase in carbohydrate contents may a result of the role of macro and micronutrients in numerous metabolic reactions, membrane integrity, starch utilization, synthesis of carbohydrate and act as co-factor in enzyme system and photochromic activities in enzyme system (Monreal et al., 2016; Bameri et al., 2012). Similarly, Seadh et al. (2009) stated that carbohydrates contents were improved with spray of B. In conclusion, a combined spray of nitrogen at tillering and boron at booting stage significantly increased the production and quality of produce in wheat. It is recommended to use both the nutrients in pertinent concentration for an economic production with higher benefits from the field.

Authors' contribution

All authors contributed equally in conceived the idea, designing the research project. UMF conducting the experiments, collect and analyze the data, write-up the research paper and making the conclusions. All authors read the final manuscript

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