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RESPONSE OF SOIL APPLICATION OF BORON TO IMPROVE THE GROWTH, YIELD AND QUALITY OF WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Background Boron is thought to be the 2nd most imperative micronutrient after zinc that can restrict plant production per unit area. Boron is included among those micronutrients that are being scarce in all types of soils. In Human beings and animals, boron has a widespread role in biochemistry and nutrition, while, inducing changes in Ca homeostasis by diverse mechanism including interaction with vitamin D and Mg metabolism.

Methodology An experiment was carried out during winter 2017-18 in the field to assess the response of soil application of boron on growth, yield and quality of wheat. Field trial was laid out at Agronomy Farm, University of Agriculture Faisalabad, Pakistan. Randomized complete block design (RCBD) was used with three replicates. Each experimental unit had size of 6.0 m × 2.25 m. The treatments were different levels of boron (0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, and 4 Kg/ha). Boron addition was done at the time of crop sowing. All the agronomic practices except treatments remained same for all plots throughout experiment.

Results Data analysis revealed a significant improvement in all the parameters observed. Total tillers (382.00 m^{-2}), productive tillers (376.33 m^{-2}), spike length (11.20 cm), grains $spike^{-1}$ (48.07), 1000-grains weight (36.07 g), final grain yield (5.27 t/ha), straw yield (5.31 t/ha), biological yield (10.58 t/ha) and harvest index (49.84%) of wheat were positively influenced by 2 kg/ha of boron addition. Grain protein contents (11.06%) and grain carbohydrate contents (69.47%) were also enhanced significantly by 2 kg/ha boron addition.

Conclusion The highest economic/grain yield was obtained when 2 kg/ha B was added at sowing time which shows that wheat yield was significantly enhanced by applying proper dose of boron at sowing time.

INTRODUCTION

Wheat scientifically called *Triticum aestivum* L. is the most important crop among all cereals. It is included in those crops which are most widely grown and was firstly domesticated worldwide. Wheat crop is valued for good taste and cheap source for different proteins, vitamins and minerals. It is included in the world's most vital crops. According to the cereals ranking in the world, it ranks 3rd while in Pakistan it stands 1st among all cereals. Globally, it provides 19% of the required calories and 21% of the required proteins per capita on daily basis (Braun et al. 2010). Total wheat growing area of Pakistan was 8740 thousand hectares which produced yield 25.195 tonnes during 2018-2019. The contribution of wheat in GDP is 1.6%, while, it shares 8.9% to the value addition in agriculture sector (Govt of Pakistan, 2019). Pakistani soils have much yield potential for wheat as compared with other countries, but per acre outcome is still very low (Sarwar et al. 2010). To increase yield per unit area, soil and crop management practices along with proper availability of nutrients to the crop is needed. Application of macronutrients is common practice while, micronutrients application is rare in Pakistan.

Micronutrients perform a vital role for the improvement of crops and help in regulation of different energy producing processes in plants (Zain et al. 2015). Micronutrients application helps in the formation of chlorophyll, nucleic acid, synthesis of

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protein and also plays an active role in enzyme activation for different enzymatic activities of photosynthesis and respiration (Reddy, 2004). Among all micronutrients, boron is only element which is least understood. Rerkasem and Jamjod (2004) reported that many plant functions are accelerated with the presence of boron.

Boron has a greater role in sexual reproduction of different crops. Ahmad et al. (2009) suggested that compared to vegetative growth, reproductive growth is more susceptible to low boron in all crop plants. Evidences showed that, in crop plants, sexual reproduction is more affected due to low boron concentration than the development of vegetative parts. Boron is required for development of pollen tube during pollination process, therefore, plays a role in good seed setting and producing healthy fruit (Rehman et al., 2018). Nectar production by flowers is thought to be increased by boron addition, and this nectar attracts pollinating insects and thus helps in pollination process.

Experiments conducted in the country recommend that the risk of boron deficiency is increasing for crop production in Pakistan and there is a need to improve management strategies and enhance knowledge for its profitable use. Boron deficiency results in failure of grain set in wheat which is linked to development of poor pollen and anthers (Goldbach and Wimmer, 2007). Deficiency of boron is well known to have an impact on the relative plant nutrient level that shows reductions in most of the scenarios. Dell et al. (2002) reported that boron is necessary for reproductive tissues and its shortage leads to low seed quality. Boron is included among those nutrients which are quickly being scarce in all types of soils. By keeping this view, present study was proposed to establish fact whether the growth, yield and quality of wheat are increased by using boron.

Many scientists have worked on boron but very less literature is found on proper level or amount of boron to be applied for high and economic wheat yield to fulfill the people's requirement. That is why, present experiment was laid out to found find the appropriate dose of boron for wheat crop.

MATERIALS AND METHODS

Experimental site and weather characteristics

A field based trial was performed executed during 2017-2018 growing season with wheat cultivar Ujala-2016 at Agronomy farm, University of Agriculture, Faisalabad-Pakistan. Experimental site is situated at 31.42º N, 73.08º E from equator with184 m elevation from sea level. Soil sampling was done at 15cm depth of field before crop sowing for physico-chemical analysis which shows the B deficiency in experimental area (Table 3). Weather data of experimental location, for the period of experimentation, is illustrated in figure 1.

Plant material and experimental design

Seeds of wheat cultivar Ujala-2016 were obtained from Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan. Wheat cultivar Ujala-2016 was selected because it was newly approved cultivar from Federal Seed Certification and Registration Department, Islamabad-Pakistan. Randomized complete block design was followed to study the above mentioned objectives with three replicates. Each plot size was 6.0×2.25 m^2 containing 10 rows with 22.5 cm row spacing.

Crop husbandry

For preparing fine seed bed, cultivator was used twice followed by planking. Seeds of Ujala-2016 cultivar were sown using manually operated hand drill. Standard N: P: K doses (120:85:60) were added. P and K was added at sowing time while N at split doses. All the agronomic measures were kept uniform throughout the course of experiment. All essential plant protective measures were also done to keep the crop free from weeds pests, diseases and insects.

Treatment plan and application

According to nutrient status of experimental field (Table 3), soil was found deficient in boron. So, following treatments were applied to achieve the above mentioned objectives; 0.0 (control), 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kg ha^{-1}. All the treatments were applied at crop sowing time by using boric acid as a source of boron.

Measurement of yield attributes

For counting total tillers and productive tillers, area of 1 m^2 was designated and total number of tillers was count manually. For the determining of length of spikes, ten plants were randomly chosen from individual plot and meter rod was used for measuring their length. Number of grains per spike counted manually from same 10 spikes and then their average was computed. For measuring 1000-grain weight, grain sample from individual plot was taken and weighed using electric balance. After the completion of harvesting, made the bundle of each plot and weighed whole bundle separately to calculate biological yield. Grain yield was obtained after the threshing of crop by electrical thresher. After threshing, grain weight of individual plot was measured by using weighing balance for total grain yield. By deducting grain yield from biological yield, remaining was straw yield.

For calculating HI following formula was used.

Table 1 Growth and yield attributes of wheat (*Triticum aestivum* L.) in response to soil application of boron

Treatment	Total tillers m^{-2}	Productive tillers m^{-2}	Spike length (cm)	Grains $spike^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})
Control	326.67 f	318.00 f	9.93 cd	41.47 e	33.67 d	4.02 f
0.5 kg B/ha	318.67 g	309.60 g	9.27 ef	45.20 c	33.77 d	4.23 d
1 kg B/ha	315.00 g	305.67 g	9.67 de	46.20 b	34.73 bc	4.12 e
1.5 kg B/ha	376.33 b	366.33 b	10.13 c	45.93 bc	35.07 b	4.82 b
2 kg B/ha	382.00 a	376.33 a	11.20 a	48.07 a	36.07 a	5.27 a
2.5 kg B/ha	365.67 d	357.00 d	9.87 cd	43.80 d	34.07 d	4.38 c
3 kg B/ha	372.67 bc	365.67 bc	10.60 b	45.80 bc	34.20 cd	4.83 b
3.5 kg B/ha	340.00 e	332.33 e	8.93 f	44.2 d	31.10 f	4.04 f
4 kg B/ha	368.67 cd	360.67 cd	10.20 bc	40.67 e	32.23 e	4.23 d
LSD value (0.05%)	4.4489	5.2034	0.4580	0.9389	0.6389	0.0504

Means of any two above values with same lettering did not significantly varied at 5% probability level

Table 2 Biological and straw yield, harvest index and quality attributes of wheat (*Triticum aestivum* L.) in response to soil application of boron

Treatment	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Carbohydrate content (%)
Control	8.71 d	4.48 cd	48.58 d	10.33 h	63.83 g
0.5 kg B ha^{-1}	8.42 e	4.30 e	48.99 bcd	10.45 g	64.83 f
1 kg B ha^{-1}	8.15 f	4.13 f	49.29 b	10.65 e	65.47 e
1.5 kg B ha^{-1}	9.87 b	5.06 b	48.79 cd	10.83 c	68.33 b
2 kg B ha^{-1}	10.58 a	5.31 a	49.84 a	11.06 a	69.47 a
2.5 kg B ha^{-1}	9.81 b	4.98 b	49.27 b	10.98 b	68.83 b
3 kg B ha^{-1}	8.94 c	4.56 c	48.97 bcd	10.74 d	67.53 c
3.5 kg B ha^{-1}	8.62 d	4.39 de	49.09 bc	10.56 f	66.60 d
4 kg B ha^{-1}	8.20 f	4.16 f	49.29 b	10.60 ef	65.73 e
LSD Value (0.05%)	0.1280	0.0935	0.4135	0.0584	0.5808

Means of any two above values with same lettering did not significantly varied at 5% probability level

Table 3 Physiochemical analysis of soil used for experimentation

Determination	Value	Satisfactory level
Sand (%)	47	-
Clay (%)	15	-
Silt (%)	38	-
Soil texture	Loamy	
pH	7.90	-
EC (dS m^{-1})	2.21	-
Saturation percentage	32	-
Nitrogen (ppm)	0.2	0.86-1.29
Phosphorus (ppm)	4.25	7-21
Potassium (ppm)	238	80-180
Boron (ppm)	0.38	0.5-1.0
Zinc (ppm)	0.75	0.79
Organic matter (%)	0.71	1.0-2.0

HI (%) = (Grain yield / Biological yield) × 100

Estimation of quality attributes

For determining grain nitrogen content, Microkjeldahl method was used which is given by Agarwal et al. (1980). For protein estimation, nitrogen contents are multiplied by factor 6.25. Gravimetric method was used to calculate the carbohydrates contents in grains (Prosky et al., 1985)

Economic Analysis

Economic analysis of crop was done by using the methodology given by CIMMYT in 1988. Net benefit cost ratio (BCR) was estimated by using the formula given below.

BCR = Gross income/Total cost

Statistical analysis

Collected data were statistically analyzed by fisher's analysis of variance technique. The difference between treatments means were compared by least difference test at probability level 5% (Steel et al., 1997).

RESULTS

Boron (B) application significantly influenced the all attributes of wheat crop. All the applied treatments significantly *$P < 0.05$)* influenced total tillers but

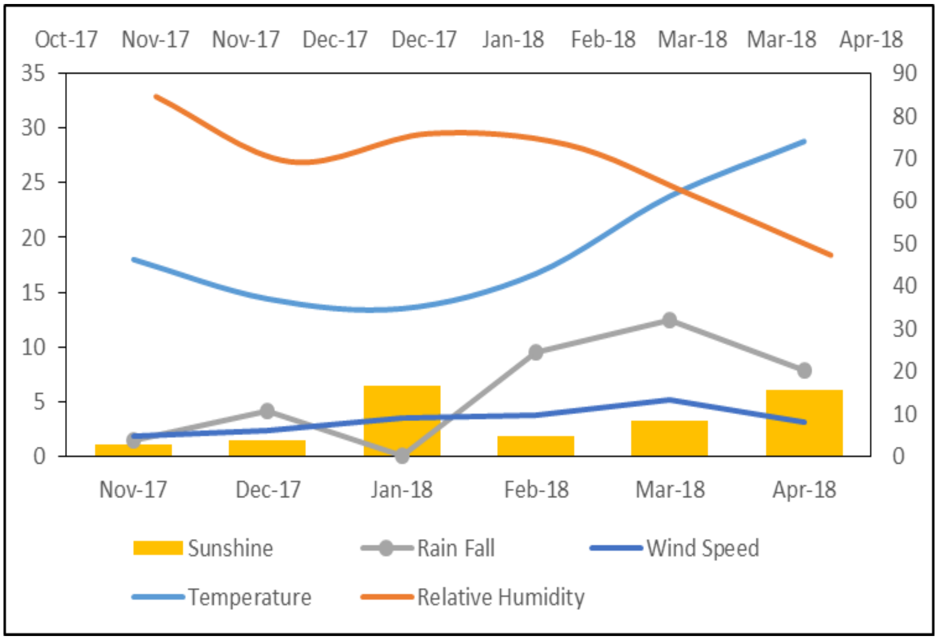

Figure 1 Weather data of experimental site during the crop season. Source: Agro-meteorological cell, University of Agriculture, Faisalabad

maximum tillers (382) were obtained by B addition at 2 kg ha^{-1} (Table 1). While, the less number of tillers (315) was noted in control treatment. Data related to the highest number of productive tillers (376) was attained by B application at 2 kg ha^{-1} (Table 1). In wheat crop, application of B positively influenced the spike length. Results revealed that significantly, the maximum spike length (11.20 cm) was obtained by application of B at 2 kg ha^{-1} while, higher dose of B (3.5 kg ha^{-1}) reduced spike length (8.93 cm) (Table 1). Addition of B at 2 kg/ha produced maximum grains per spike (48) while less number of grains per spike (40) was noted by addition of B at 4 kg ha^{-1} (Table 1).

Boron application at the time of sowing remarkably influenced the 1000-grain weight in wheat, maximum 1000-grain weight (36.07 g) was obtained by application of B at 2 kg ha^{-1} (Table 1) while, 1000-grain weight was minimum (31.10 g) by application of B at 3.5 kg ha^{-1}. Highest grain yield (5.27 t/ha) was produced by B application at 2 kg ha^{-1}while, least grain yield (4.04 t ha^{-1}) was recorded by increasing the dose of B (3.5 kg ha^{-1}) (Table 1). Similar trend was observed in biological and straw yield (Table 2). Significantly, the maximum harvest index (HI) was documented (32.19%) by application of B at 2 kg ha^{-1}, however, B application at 1.5 and 3.0 kg/ha showed same results (Table 2).

Application of B significantly ($P < 0.05$) improved the quality attributes of wheat grains. Soil application of B at 2 kg ha^{-1} produced maximum protein contents (11.06%) of wheat grain (Table 2) while the lowest protein contents (10.56%) were attained by B application at 3.5 kg ha^{-1}. Significantly the higher grain carbohydrate contents (69.47%) were recorded from application of B at 2 kg ha^{-1}while, the lowest carbohydrate contents (63.83%) were attained in control treatment (Table 2).

DISCUSSION

In the present study the addition of boron at the time of sowing significantly enhanced the growth, yield and quality attributes of wheat. The application of boron increased the number of total and productive tillers (Table 1). These outcomes with increased number of tillers are correlated with Nadim et al. (2011) who obtained same results from their experiment and the reason behind this increase in total tillers is role of B in cell wall establishment at early growth stages which enhanced overall crop growth and development process. Khan et al. (2006) also showed significantly increased productive tillers by applying boron. Reason for increase in productive tillers is function of B in reproductive growth of wheat crop. Spike length and grains per spike were also positively influenced by boron application (Table 1).These findings are similar with Leghari et al. (2016) who perceived that there is an increase in spike length when proper amount of B was added at the time of sowing. Uddin et al. (2008) noted maximum grains per spike by applying boron. Reason for enhancement in grains per spike is that boron having a vital role in food material translocation within plants, therefore, it has a greater role in grain setting and ultimately increases grains per spike.

The 1000-grain weight was also increased by boron addition and these outcomes are correlating with Soylu et al. (2004) who obtained maximum 1000-grain weight by boron addition at sowing time and reason for increasing 1000-grain weight is that boron addition influenced pollination process which ultimately increased seed production in spikes. Grain yield also increased by boron application (Table 1) and these outcomes are correlated with Nadim et al. (2011) who attained maximum grain yield in wheat crop with boron addition. Likewise, Chaudhry et al. (2007) also concluded that B application accompanied with basal NPK dose remarkably raised the yield of wheat crop. Boron application also had positive effect on biological and straw yield which is supported by Khan et al. (2010) as they documented that biological yield was enhanced by boron application due to enhancement in productive tillers and grain yield. Uddin et al. (2008) also observed that wheat straw yield was increased significantly by applying boron. Reason for increase in straw yield is boron played a greater role in the reproduction process than in newly developed tissue in crop. Harvest index was too influenced positively with boron application at sowing time (Table 2) which is correlated with the outcomes of Tahir et al. (2009) who laid out a field experiment and concluded that applying boron significantly enhanced the HI of wheat crop.

Quality attributes of wheat crop were also improved by boron (Table 2). This improvement might be due to the role of boron in flowering and fruit formation. Boron also possesses an imperative role in regulating the different metabolic processes occurring within plants and thus increased protein contents. While reason for increasing carbohydrate contents might the function of B in sugar translocation and regulation of metabolic processes. This increase in carbohydrates concentration is correlated with Rashid et al. (2006) who noted 7-21% increased concentration of carbohydrates in many experimental crops.

CONCLUSION

Application of boron at various concentrations significantly improved the growth of wheat. Highest grain yield, straw yield, biological yield and crop harvest index were recorded by soil applied B at 2 kg ha^{-1}. Soil applied B at 2 kg ha^{-1} seems promising to improve the productivity and quality of wheat crop grown under B deficient soils.

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