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Effects of foliar application of boron on yield and yield associated traits in wheat (*Triticum aestivum* L.)

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Abstract
Boron is an important micronutrient affecting plant growth and yield. However, boron application to crops is not a common practice. A field experiment was conducted in wheat crop at the N. E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar during 2020-21 to analyse the effects of different concentrations and the time of foliar application of borax and boric acid on wheat crop. Foliar application of boron in either form significantly increased wheat yield by improving different yield attributes. Two sprays of 0.1% and 0.2% borax was found to be most effective for increasing yield and yield related parameters. Grain yield was 27.6% higher with two sprays of 0.2% borax. Total B uptake by the plant was 1.26 fold higher than control when 0.1% borax was applied at 30 and 60 days after the crop emergence.

Keywords: Boron, foliar spray, boron uptake, yield attributes

Introduction

Wheat is the major staple food crop, providing almost half of all calories in the North Africa and West and Central Asia. The production of wheat has been increasing from 87.39 million tonnes in 2012-13 and has reached a record 94.57 million tonnes in 2017–2018 (Ramadas *et al*., 2019) [6]. Wheat is known to respond to the application of several macro and micronutrients during its growing stages which can increase yield. Micronutrients such as zinc, copper, iron, manganese, boron, molybdenum and chlorine are though required by plants in much smaller amounts, yet are as essential as the major nutrients N, P and K (Singh *et al*., 2015) [8]. Due to declining soil quality and a lack of micronutrients, which results in lower yield and quality of grain, the sustainability and productivity of wheat cropping system will be adversely affected if nutritional supplements are not changed/modified (Kumar *et al*., 2016) [4].

Boron is one of the seven essential micronutrients required for the normal growth of most of the cereal, fruit and vegetable crops. It is the only non-metal among the seven plant micronutrients. Since its discovery as an essential trace element, the importance of boron as an agricultural chemical has grown very rapidly. Boron is unique among the essential mineral micronutrients because it is the only element that is normally present in soil solution as non-ionized molecule over the pH range suitable for plant growth. Recently, boron is considered to be possibly essential for animals and humans health. Deficiency of boron causes severe reductions in crop yield, due to severe disturbances in B-involving uptake and transport processes, cell wall synthesis, cellular membrane functions (Fakir *et al*., 2016) [1], and phenol metabolism (Tanaka and Fujiwar, 2008) [9]. Longitudinal splitting of the newer leaves of wheat close to the midrib results in a saw tooth effect on the margins during the vegetative stage of wheat. Boron deficiency also depresses pollen germination adversely affecting the fertilization process and ultimately resulting in poor grain setting (Rerkasem *et al*., 1997) [7].

Micronutrients can be applied in different ways such as seed priming, soil application and fortification, but foliar application is reported to be more beneficial (Bameri *et al*., 2012). Foliar application is done at later stages of crop growth when crop stands are already established; this method of B application has been found more effective in yield improvement and grain enrichment (Johnson *et al*., 2005) [2]. Application of micronutrients enhances physiological processes in plant, resulting in enhanced growth and dry matter production. The increase in biological yield with increase in boron application might be due to good balance between photosynthesis and respiration. The final yield depends on translocation of photosynthates from the source to sink which is also regulated to some extent by boron. Boron removal alters cell wall physics and reduces the translocation of photosynthates which results in reduced seed yield (Kumararaja *et al*., 2015) [5].

Materials and Methods

A field experiment was conducted during winter season of 2020-21 at N. E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Wheat variety PBW343 was sown in early November and harvested in early April. The experiment was set up in a randomized block design with three replications for each treatment. Two boron sources were used for foliar application i.e. borax and boric acid. Treatments consisted of control (without boron), 0.1% and 0.2% Borax, 0.0625 and 0.125% Boric acid, corresponding to 0, 113.6, 226.6, 109.25 and 218.5 ppm Boron respectively. Boron was applied either as one spray at 30 days after emergence (DAE), or as two sprays, one each at 30 and 60 DAE. In control, an equal volume of distilled water was used. 320g urea was added to the spray solution for each treatment.

Table 1: Effect of foliar application of boron on biological yield (t/ha) of wheat genotype PBW 343

Foliar application	Biological Yield (t/ha)		
	S1 (30 DAE)	S2 (30 & 60 DAE)	Mean
Control	9.82	10.28	10.05^{C}
0.1% Borax	11.50	14.34	12.92^{A}
0.2% Borax	13.59	13.24	13.42^{A}
0.0625% Boric acid	11.36	12.70	12.03^{B}
0.125% Boric acid	12.36	13.16	12.76^{A}
Mean	11.73	12.74	

S1: One spray at 30 days after emergence; S2: Two sprays, one each at 30 and 60 days after emergence
Values with same letters shows no significant differences at 5% level by Tukey's honestly significant difference (HSD test)

Table 2: Effect of foliar application of boron on grain yield (t/ha) of wheat genotype PBW 343

Foliar application	Grain Yield (t/ha)		
	S1 (30 DAE)	S2 (30 & 60 DAE)	Mean
Control	4.71	5.04	4.88^{C}
0.1% Borax	6.14	6.43	6.29^{AB}
0.2% Borax	6.09	6.65	6.37^{A}
0.0625% Boric acid	6.08	6.17	6.13^{BC}
0.125% Boric acid	6.02	6.08	6.05^{B}
Mean	5.81	6.07	

S1: One spray at 30 days after emergence; S2: Two sprays, one each at 30 and 60 days after emergence
Values with same letters shows no significant differences at 5% level by Tukey's honestly significant difference (HSD test)

Table 3: Effect of foliar application of boron on straw yield (t/ha) of wheat genotype PBW 343

Foliar application	Straw Yield (t/ha)		
	S1 (30 DAE)	S2 (30 & 60 DAE)	Mean
Control	5.11	5.23	5.17^{C}
0.1% Borax	5.32	7.91	6.62^{AB}
0.2% Borax	7.50	6.59	7.05^{A}
0.0625% Boric acid	5.28	6.53	5.91^{BC}
0.125% Boric acid	6.35	7.08	6.72^{AB}
Mean	5.91	6.67	

S1: One spray at 30 days after emergence; S2: Two sprays, one each at 30 and 60 days after emergence
Values with same letters shows no significant differences at 5% level by Tukey's honestly significant difference (HSD test)

Table 4: Effect of foliar application of boron on the harvest index and test weight (g) of wheat genotype PBW 343

Foliar application	Harvest Index (%)			Test Weight (g)		
	S1 (30 DAE)	S2 (30 & 60 DAE)	Mean	S1 (30 DAE)	S2 (30 & 60 DAE)	Mean
Control	48.05	49.15	48.60^{AB}	36.43	37.66	37.05^{C}
0.1% Borax	53.46	44.83	49.15^{AB}	38.54	38.81	38.68^{B}
0.2% Borax	44.91	50.26	47.59^{B}	38.57	39.05	38.81^{B}
0.0625% Boric acid	53.53	48.57	51.05^{A}	38.17	38.52	38.35^{B}
0.125% Boric acid	48.71	46.18	47.45^{B}	40.23	40.21	40.22^{A}
Mean	49.73	47.80		38.39	38.85	

Results

Yield and yield related traits

Foliar application of borax and boric acid significantly affected biological yield (Table 1), grain yield (Table 2), and Straw Yield (Table 3). Even the test weight and harvest index were also significantly affected (Table 4). Application of 0.1 - 0.2% borax and 0.06 - 0.125% boric acid increased the biological yield of wheat significantly over control. Among boron treatments, maximum biological yield (13.6 t/ha) was obtained with a single spray of 0.2% borax which was 38.4% higher over the control while the minimum biological yield (11.4 t/ha) was obtained with a single foliar application of 0.06% boric acid. Biological yield, grain yield and straw yield were significantly affected by spray concentration of boron while spray frequency had no significant effect. Maximum grain yield (6.65t/ha) and straw yield (7.91 t/ha) was recorded with two sprays of 0.1% and 0.2% borax which was 26% and 51.24% higher, respectively over the control. In comparison to single foliar application two foliar sprays of 0.125% boric acid caused a significant decrease in biological yield of wheat. Two foliar applications at 30 and 60 DAE had a significant effect on the grain yield of wheat and increased mean grain yield by 3.7 percent as compared to that with a single spray at 30 DAS. The mean straw yield of wheat significantly increased by 24.8 to 51.20 % as compared to that in control at different concentrations of boron.

At different concentrations of borax and boric acid, the mean test weight increased by 6.71, 7.22, 3.98, 4.39 and 4.18% while the mean harvest index increased by 0.07% and 4.84% with 0.2 and 0.06% borax and boric acid sprays respectively and decreased by 0.05 and 4.33% with 0.2 and 0.125% borax and boric acid sprays respectively. Among the treated plants, maximum (40.02g) test weight with increment of 6.97% over control and harvest index with 15.14% was observed with two and one spray of 0.1 and 0.06% of borax and boric acid, respectively.

Total Boron uptake and correlation between different yield related attributes

Application of 1.0 and 2.0 g borax/l and of 0.625 and 1.25 g boric acid/l increased the mean total B uptake of wheat significantly (Figure 1). There were up to 1.12 to 1.34 fold increase in B uptake control, respectively. Application of 0.1% borax was found most effective in increasing total boron uptake by 1.26 folds over control. A correlation between grain yield and total boron uptake (Figure 2) shows positive correlation coefficient value ($R^2 = 0.8935^{**}$). B concentration and yield related parameters shows significant level of correlation (Figure 3) except for harvest index and straw yield which shows statistically insignificant correlation values. In addition, number of sprays was not correlated with any yield related parameters except straw yield.

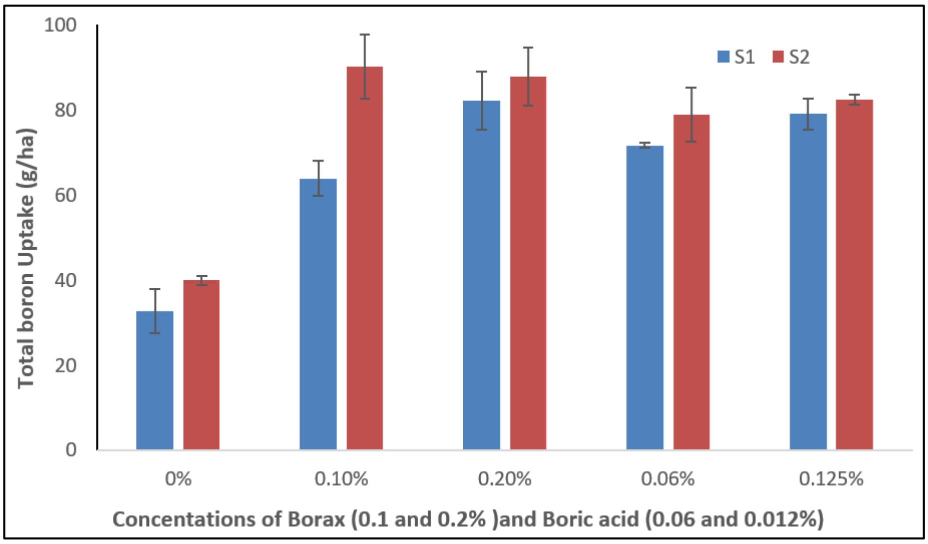

Fig 1: Effect of foliar application of boron on total B uptake of wheat genotype PBW 343.
(S1: One spray at 30 days after emergence; S2: Two sprays, one each at 30 and 60 days after emergence)

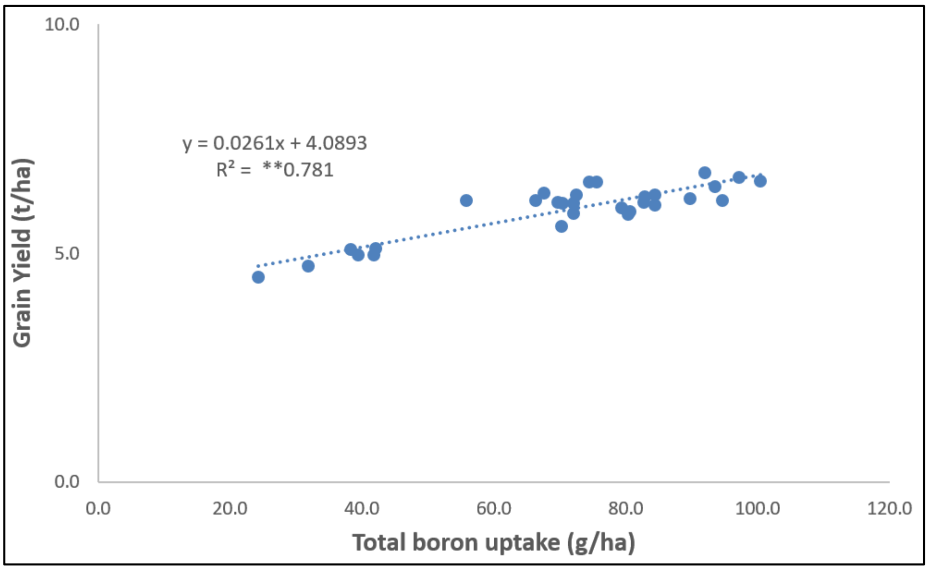

Fig 2: Correlation between grain yield and total boron uptake in wheat genotype PBW 343
**Significant at *p*<=0.01

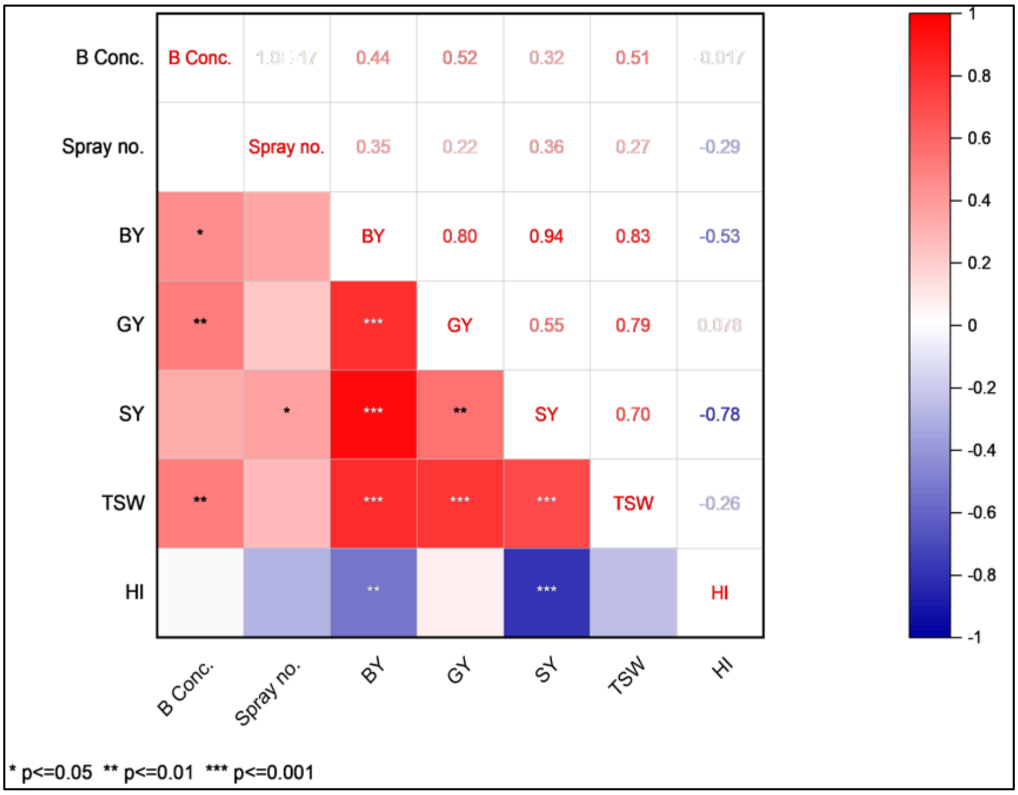

Fig 3: Correlation between different yield related attributes at different concentration of boron.
BY: Biological yield, GY: Grain yield, SY: Straw yield, TSW: Test weight, HI: Harvest Index

Discussion

Boron is important and essential micronutrient in plant growth and development and efficiently improves production of wheat crop. Concentration of boron in soil and bioavailability is affected by various factors which includes texture of soil, clay particles nature, pH, temperature, organic matter content, and environment related conditions such as rainfall, light intensity and dry. In the view of above, the present study was carried to investigate the effect foliar application of boron and spray frequency on yield and yield related traits in wheat. From the above results it was observed that boron application significantly affects 1000 grain weight, harvest index, Biological yield, grain yield and straw yield. 1000 grain weight is significantly affected by boron application, one of the reason is that boron requirement is more in reproductive stage in comparison to other stage which results healthy grain with more weight. Grain yield of crop plants is combined effect of different yield related attributes. Yield is affected by boron as it is directly related with fertilization process, pollen viability, germination and pollen tube growth.

Conclusion

Foliar application of B shows significant effect of yield associated traits and total B uptake in wheat crop. Yield and various yield related attributes shows maximum increase at 0.2% concentration of borax at two sprays (60 DAE).

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