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Original Research Article

Effects of Foliar Application of Boron (B) on the Grain Set and Yield of Wheat (*Triticum aestivum* L.)

ABSTRACT

Aims: The Objectives of this study were to find out the effect of foliar application of boron on the grain set and yield components of wheat, the best time of foliar application of boron for overcoming B deficiency and obtaining higher crop yield.

Study design: The experiment was laid out in a randomized complete block design (RCBD) with six treatments and three replications.

Place and Duration of Study: The experiment was studied through a field experiment at Bangladesh Agricultural University (BAU) farm, Mymensingh during 2010-11 rabi season.

Methodology: The treatments were- (i) B control, (ii) soil application, (iii) seed priming, (iv) foliar spray at primordial stage, (v) foliar spray at booting stage and (vi) foliar spray at primordial stage and booting stages. Boric acid was used as a source of boron. The rate of B for soil application was 1.5 kg ha-1 from boric acid and the rate for each foliar spray was 0.4% boric acid solution. Seed priming was done by soaking wheat seeds into 0.1% boric acid solution for 10 hours and then seeds were dried before sowing.

Results: The treatment receiving foliar spray at primordial stage and also booting stages and at booting stage only performed the highest yield (3625kg ha-1) which was identical with the yields obtained with foliar spray at primordial stage only or soil application of B, ~~all~~ the yields were significantly higher over the yields of seed priming and control treatments. The B control treatment had the lowest grain yield (2600 kg ha-1) which was significantly lower than the yield recorded with seed priming treatment.

Conclusion: Overall result indicates that the experimental field is deficient in boron and this deficiency can be overcome effectively by soil application of B @ 1.5 kg ha-1 or foliar application of boron (0.4% boric acid solution) at booting stage of crop.

Keywords: Foliar application; Boron; Booting stage; Wheat; Grain set; Yield

1. INTRODUCTION

Wheat, next to rice, is the most important cereal crop in this country and in the world it ranks first both in area and production and about the two thirds people of the globe lives on wheat grains. Wheat grain has high food value with 14.7% protein, 2.1% fat, 78.1% starch and 2.1% mineral mater [1]. There are some advantages of growing wheat instead of rice in Bangladesh: (i) investment is less for wheat cultivation. So small farmer can go for its cultivation, (ii) irrigation water requirement is 1/3 rd or ¼th than the requirement for rice, (iii) little weed or insect pest infestation and (iv) assurance of next crops after harvest [2]. Unfortunately the areas and production of wheat in our country have declined after 1982 [3]. In order to meet the food deficit in Bangladesh and to cope with the food demand for the increasing population, wheat production needs to be increased. The yield of wheat is low in Bangladesh and boron deficiency can be marked as a main cause of it. Boron requirement may vary among plant species and also within the genotypes of a species [4]. Boron plays a vital role in the physiological processes of wheat plant such as cell elongation, cell maturation, sugar translocation, meristematic tissues development, protein synthesis and ribosome for mutation [5]. Boron requirement may vary with plant to plant species and genotypes within a species [6]. Boron deficiency causes grain sterility in wheat as reported by Li et al. [7] in China, Mandal and Das [8] in India, Rerkasem et al. [6] in Thailand, Sthapit [9] in Nepal and Jahiruddin et al. [10] in Bangladesh. In 1990s the B deficiency was observed in some soils and crops in Bangladesh. Boron deficiency is more evident in rabi or winter crops, e.g. mustard, wheat, chickpea and less evident in rice crop. Boron deficiency of crop is the second most widespread micronutrient problem in

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Bangladesh. The intensive cropping with HYV crops, low organic matter status and sandy texture has favored the occurrence of B deficiency in Bangladesh soils. Gupta [5] states that because of its non-ionic nature once B is released from soil minerals it can be leached out from the soil fairly rapidly. The available boron content of most sandy acid soils varied from 0.1 to 0.3 mg/kg in Bangladesh [11]. As general guidelines for B fertilizer recommendations, Cooke [12] suggests that when the hot water soluble B in soil is less than 0.5 mg kg^{-1}, deficiency is likely to occur and all crops are to be treated with B; when it is 0.5-1.0 mg kg^{-1}, deficiency may appear and insurance dressings are to be considered; when it is more than 1.0 mg kg^{-1}, deficiency is unlikely and B treatment is not necessary; and when it is 3-5 mg kg^{-1}, crops may be poisoned from excess B. Thus, a careful and judicious application of boron is necessary. Efficiency of B application depends on the time and method of B application. Jolanta Korzenniows [13] conducted a field trial, involving foliar application of boron to evaluate the effect of foliar spray of boron on different cultivars of wheat. Foliar fertilization treatments caused a significant grain yield increase of four out of ten winter wheat cultivars. The average yield increment ranged between 9 and 15%. Marphy and Walsh [14] in their comprehensive review emphasize that B application needs to be made a number of times throughout the growing season because of the immobility of the element in the plant. In fertilizer schedule an inclusion of B often decides the success and failure of the crops [15]. It is reported that the range between deficiency and toxicity of B is quite narrow and an application of B can be extremely toxic to plant at concentrations only slightly above the optimum rate [16]. There are many reports on the positive response of crops to boron application [17, 18, 19]. Boron can be applied as soil application and foliar spray. Soil application is a common practice of fertilizer application. For micronutrients when plants receive small amount, other methods like foliar spray and seed priming might be equally effective as soil application. Further, the latter two methods would be more economic since they will require much smaller amount of boron. Foliar spray of boron could be better for two reasons – (i) the amount of boron fertilizer would be at least five times less and (ii) T. Aman rice generally does not respond to boron application, so residual effect of soil applied boron would be of no value. With the above understanding, a study was made to evaluate the effect of foliar application of boron on the yield response and grain set of wheat (Triticum aestivum L.) at BAU farm, Mymensingh (AEZ 9).

2. MATERIALS AND METHODS

2.1 Site of soil

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) farm, Mymensingh during 2010-11. The experimental field is located at 24.75° N latitude and 90.50° E longitude at a height of 18m above the mea n sea level. It was a medium high land. The soil was Sonatala silt loam, a member of Aeric Haplaquept. It belongs to the order Inceptisol having only few horizons, developed under aquic moisture regime. General characteristics of the soil are presented in Table 1.

Table 1. Morphological, physical and chemical characteristics of the soil
A. Morphological characteristics

AEZ	Old Brahmaputra Floodplain (AEZ 9)
General soil type	Non-calcareous Dark Grey Floodplain Soils
Parent materials	Brahmaputra river borne deposits
Drainage	Moderate
Topography	Medium high land
Flood level	Above flood level

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B. Physical characteristics

% Sand	20.4
% Silt	68.0
% Clay	11.6
Textural class	Silt loam

C. Chemical characteristics

Characteristics	Content	Interpretation
pH (soil: water = 1:2.5)	7.30	Near neutral
Organic matter (%)	0.81	Very Low
Total N (%)	0.06	Low
Available P (mgkg-1)	7.29	Low
Available K (c mol kg-1)	0.06	Low
Available S (mg kg-1)	10.0	Low
Available Zn (mg kg-1g)	0.84	Low
Available B (mg kg-1)	0.15	Low

2.2 Climate

The experimental area has a sub-tropical humid climate, which is characterized by high temperature, high humidity and high rainfall with occasional gusty winds in the kharif season and low rainfall associated with moderately low temperature during rabi season.

2.3 Experimental design

The experiment was laid out in a randomized complete block design (RCBD). There were six boron treatments, each replicated three times. The boron treatments were distributed to main plots and wheat genotypes to the sub-plots. The number of plots was 6×3 = 18. The unit plot size was 4 m×5m. The plot-to- plot distance was 0.5 m and block - to- block distance was 1m.

2.4 Treatments

There were six boron treatments including 1-control as follows:

T1 = Control

T2 = Soil application of B @ 1.5 kg ha^{-1} (designated as SA)

T3 = Seed priming (wheat seed soaked in 0.1% boric acid solution for 10 hours before sowing (designated as SP)

T4 = Foliar spray @ 0.4% boric acid solution at primodia stage of crop growth (designated as FS-p)

T5 = Foliar spray @ 0.4% boric acid solution at booting stage of crop growth (designated as FS-b).

T6=Foliar spray at primodia and booting stages (designated as FS-pb).

2.5 Fertilizer application

Fertilizers were applied to each plot as per treatments. Besides boron, every treatment received 115 kg N ha^{-1}, 25 kg P ha^{-1}, 75 kg K ha^{-1} and 15 kg S ha^{-1}. Fertilizers such as urea, TSP, MoP, gypsum and boric acid were used as sources for N, P, K, S, and B, respectively. One-third dose of urea and full dose of all other fertilizers were applied as basal to the individual plots during final land preparation. The second split of urea was applied after 30 days of sowing (crown root stage) and the third split after 55 days (booting stage). Boron was applied as per treatments. For foliar spray treatments, boric acid solution was sprayed at 55 and 75 days after sowing to represent primodia and booting stages of crop, respectively.

2.6 Intercultural operations

Top dressing of urea was done as per schedule and the normal cultural practices including weeding and insecticide spray were done as and when required. Two irrigations were provided after 25 and 55 days of

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sowing. Weeding was done twice during the whole growth period, the one after 21 days of sowing and the other after 50 days. The field was attacked by armyworm (*Mythumna separata*) which was successfully controlled by using Akonazol.

2.7 Data collection

The data were mainly yield and yield components. The yield data included grain and straw yields, and the growth and yield components included plant height, number of tillers m^{-2}, spike length, number of spikelets $spike^{-1}$, spike length, number of spikelets $spike^{-1}$, number of filled grains $spike^{-1}$, and 1000-grain weight. These data were taken at harvest of the crop. Due attention was given to recording the grain set data since evaluation of grain set as influenced by boron was a prime objective of the present study. With this point of view, five plants were randomly collected from each plot and the number of grains $spike^{-1}$, 1000 grain weight and the number of spikelets $spike^{-1}$were noted. Other parameters like plant height, number of tillers m^{-2} and spike length were also recorded. The grain and straw yields were recorded on each plot.

2.8 Statistical analysis

The analysis of variance (ANOVA) for various crop characters and also for nutrient concentrations and uptake were done following the principle of F-statistics. Mean comparison of the treatments were adjudged by the Duncan's Multiple Range Test [20]. Correlation statistics was performed to examine the interrelationship among the plant characters under study.

3. RESULTS AND DISCUSSION

The growth and yield components include plant height, tillers $plant^{-1}$, spike length, spikelets $spike^{-1}$, grains $spike^{-1}$ and 1000-grain weight. The data were recorded at maturity of the crop. These plant characters are discussed below.

3.1 Plant height

Boron application had no significant effect on the plant height of wheat, cv. Shatabdi (Table 2). However, the highest plant height was recorded with the treatment that received foliar spray of B at primordial stage of the crop and the smallest plant was observed with the B control (90.2cm). Insignificant effect of B on plant height of wheat has also been reported in the past. Mandal and Das [8] in India and Abedin et al. [11] in Bangladesh also did not observe significant effect of B on plant height of wheat.

3.2 Tillering

Like plant height, the tillers $plant^{-1}$ was also not influenced significantly by B treatments. In value, the treatment having soil application of B recorded the highest number of effective tillers m^{-2}. The number of tillers m^{-2} over the treatments varied from 2.83-3.60. All the B treatments produced higher number of tillers m^{-2}, compared to B control.

3.3 Spike length

Like plant height and tillering, the spike length remained unaffected by boron added to seed, soil or plant as foliar spray (Table 2). Spike length varied within a narrow range from 9.10cm in control to 9.84cm. The highest spike length was found in T5 treatment (foliar spray of B at booting stages). Mandal and Das [8] in India also observed that B application to soil @ 10, 15 and 20 kg ha^{-1} failed to show significant effect on spike length of wheat.

Table 2. Effects of different B treatment on plant height, tillers $plant^{-1}$ and spike length of wheat

Boron treatments	Plant height (cm)	Tillers $plant^{-1}$ (no.)	Spike length (cm)
T1: Control	90.2	2.83	9.10
T2: SA	95.9	3.60	9.83

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T3: SP	93.8	3.06	9.54
T4: FA-p	97.1	3.10	9.71
T5: FA-b	94.1	3.16	9.84
T6: FA-pb	93.8	3.23	9.41
Level of significance	NS	NS	NS
CV (%)	3.59	13.98	3.36
S.E. (±)	11.45	0.197	0.103

values in a column having same letter do not differ significantly at 5% level by dmrt

NS = Not significant , S.E = Standard error of means, CV = Coefficient of variation ,SA = Soil application @ 1.5 kg B ha-1; SP = Seed priming with 0.1% boric acid solution for 10 hours; FS-pb = Foliar spray @ 0.4% boric acid solution at primodia and booting stages of crop.

3.4 Spikelets spike^{-1}

The number of spikelets spike^{-1} varied significantly due to boron treatments (Table 3). Every method of boron application except T_3 (seed priming) significantly produced higher number of spikelets spike^{-1} over B control (T_1). The highest number of spikelets spike^{-1} was observed with the treatment having foliar spray of B at primodia stage (T_4) that was not significantly different from that of soil application of B (T_2), but significantly different seed priming (T_3).

3.5 Grains spike^{-1}

Boron treatments resulted in a significant improvement in the number of grains spike^{-1} (Table 3). All foliar applied B treatments and also soil treatment of B resulted is significantly higher number of grains spike-1 over seed priming and B control treatments. Again, seed priming with boric acid solution produced higher number of grain spike^{-1}, compared to control. Such result, thus, indicates that grain unfilling in wheat occurs due to B deficiency and the problem can be overcome by boron either added to soil or seed or to plant as foliar spray.

3.6 Thousand grain weight

Boron application had significant effect on 1000-grain weight of wheat (Table 3). The 1000-grain weight varied among the treatments with a range of 44.48 (B control) to 54.74 (foliar spray at primodia and booting stages of the crop). However, foliar application of B either at booting stage or at primodia and booting stages of the crop, grain weight remained same statistically. The least 1000-grain weight was recorded by B control treatment like other parameters, T6 treatment showed the heaviest grain and T0 (B control) did the lowest.

Table 3. Effects of different B treatments on spikelets spike^{-1}, grains spike^{-1} and 1000-grain weight of wheat.

Boron treatments	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	1000-grain weight (g)
T1: Control	15.43 d	15.17 c	44.48 d
T2: SA	17.03 ab	41.73 a	48.73 bc
T3: SP	15.67 cd	31.47 b	47.78 c
T4: FA-p	17.23 a	39.60 a	48.55 bc

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T5: FA-b	16.37 bc	39.60 a	51.59 ab
T6: FA-pb	16.10 bd	38.17 a	54.74 a
Level of significance	*	**	**
CV (%)	2.74	9.65	3.67
S.E. (±)	0.200	10.94	3.275

data are an average of three replications. *=significant at 5% level; **=significant at 1% level

3.7 Grain yield

Grain yield was the most important parameter of this study. The grain yield of wheat (cv. Shatabdi) was significantly influenced by boron application (Table 4 and Fig. 1). Significantly higher grain yield was obtained in soil and added B treatments and the next higher yield was observed with seed priming of B treatment. The grain yield ranged from 2600 to 3625 kg ha^{-1}. The seed priming-B treatment gave statistically higher grain yield across the six B treatments, including control. Foliar spray at booting or primordial or both stages of crop gave identical yields. Yield benefits due to T2, T3, T4, T5 and T6 treatments were 27.5%, 15.6%, 26.5%, 30% and 30% yield increase over control, respectively. The available B content of soil under study was 0.15 mg kg^{-1} which as per Fertilizer Recommendation Guide [21] was inadequate to support normal plant growth. Thus, the present experiment shows a good correlation between soil test value and crop response. The higher yield of wheat as obtained with B treatments agrees well to the findings of Jahiruddin et al. [10], Abedin et al. [11] and Ahmed et al. [22] in Bangladesh. Such positive response to B application is also reported in other countries, as in Thailand [6], China [7], India [23], and Nepal [9].

3.8 Straw yield

The straw yield did not increase significantly due to B application either to seed, soil or plant (Table 4). In values the lowest yield (5625 kg/ha) was observed with B control and the highest yield (6388 kg/ha) with B application at primodia and booting stages of crop. Yield advantages were due to T5 and T6 treatments were 11.8% and 12.0% increase over control, respectively.

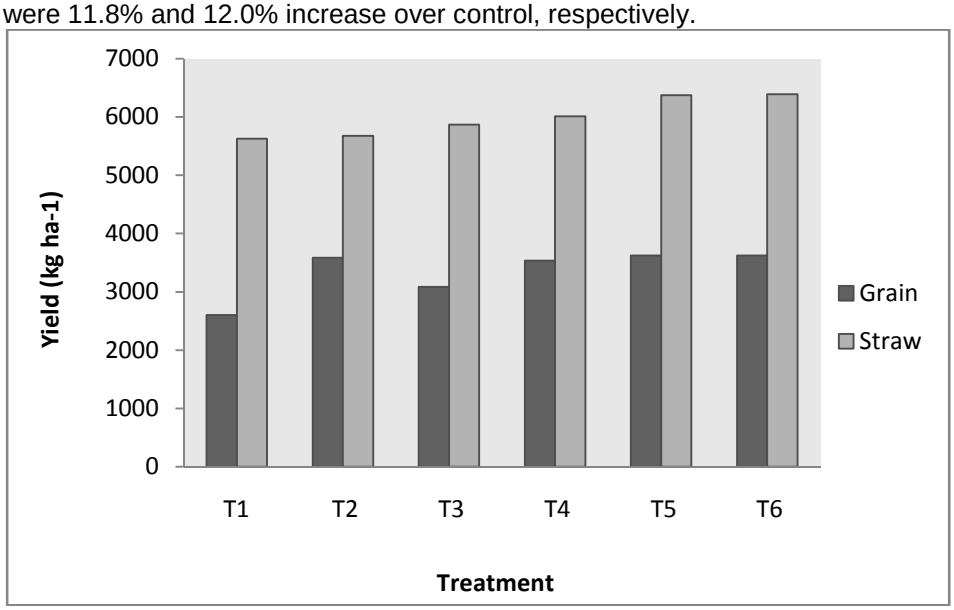

Fig. 1 Effects of different methods of boron application on the grain and straw yields of wheat

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Table 4. Effects of different B treatments on the grain and straw yields of wheat

Boron treatments	Grain yield (kg ha^{-1})	% yield increase over control	Straw yield (kg ha^{-1})	% yield increase over control
T1: Control	2600 c	-	5625	-
T2: SA	3583 a	27.5	5676	0.9
T3: SP	3083 b	15.6	5870	4.1
T4: FA-p	3533 a	26.5	6011	6.4
T5: FA-b	3625 a	30.0	6375	11.8
T6: FA-pb	3625 a	30.0	6388	12.0
Level of significance	**	-	NS	-
CV (%)	4.15	-	12.64	-
S.E. (±)	0.019	-	0.649	-

values in a column having same letter do not differ significantly at 5% level by dmrt

3.9 Correlation of crop yield with other plant characters

Grain yield is a complex character that results from contribution of several plant parameters (Table 5). The grain yield was positively and significantly correlated with plant height (r= 0.518; P< 0.05), number of tillers per plant (r=0.543; P< 0.05), spike length (r=0.485; P< 0.05), spikelets spike^{-1} (r= 0.580; P< 0.05), grains spike-1 (r= 0.775; P< 0.01) and 1000- grain weight (r=0.720; P< 0.01), Like grain yield, the straw yield was positively correlated with plant height and spike length only. There was no relationship between grain and straw yields of wheat (r= 0.146; P< 0.01). The results indicate that the number of grains spike-1 and 1000- grain weight, among the yield contributing characters, had the highest influence on the grain yield of wheat. This result otherwise indicates that the grain set of wheat is interrupted by boron deficiency and it can be corrected by B application.

Table 5. Correlation matrix among the yield contributing characters, grain yield and straw yield of wheat (n=18)

Variables	Plant height	Tillers plant^{-1}	Spike length	Spikelets spike^{-1}	Grains spike^{-1}	1000-grain weight	Grain yield	Straw yield
Plant height	1							
Tillers plant^{-1}	0.374NS	1						
Spike length	0.081NS	0.263NS	1					
Spikelets spike^{-1}	0.124	0.388	0.777**	1				

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Grains spike-1	0.448	0.303	0.573*	0.608**	1			
1000-grain weight	0.104	0.218	0.402	0.339	0.621**	1		
Grain yield	0.518*	0.543*	0.485*	0.580*	0.775**	0.720**	1	
Straw yield	0.076*	0.123	0.535*	0.166	0.116	0.192	0.146	1

4. CONCLUSION

Except the plant height, the number of tillers plant^{-1} and spike length, all other plant characters like spikelets spike^{-1}, grains spike^{-1}, 1000 grain weight and grain yield were significantly influenced by the B treatments. On the other hand, the straw yield was unaffected by B supplement. Comparing the performances of different methods of boron application, foliar spray particularly at booting stage (T5) performed the highest grain yield (3625Kg ha^{-1}) which was significant over seed priming and B control treatments. All foliar B spray treatments and also soil B treatment gave identical grain yield. The highest number of grains spike^{-1} and spikelets spike^{-1} was also found in foliar spray of B at booting stage of crop (T5). The B control treatment had the lowest grain yield (2600 kg ha^{-1}). Treatments T5 and T6 both gave a 30% yield benefit over the B control. The results of the experiment indicate that the field was deficient in boron and B deficiency depressed commercial wheat yield primarily through grain set failure. Boron application exerted significant influence on the grain set and yield of wheat. So for efficient wheat production in this soil, an application of boron is essential. The present study also shows that foliar application of boron at booting stage of crop can successfully eliminate the B deficiency and increase wheat yield. This result would be applicable to the BAU farm and its adjacent areas which belong to the Old Brahmaputra Floodplain agro-ecological zone (AEZ-9).

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