Original Research Article

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

ABSTRACT

Aims: The Objective of this study was to evaluate the effect of foliar application of boron (B) on the grain set and yield of wheat (cv. Shatabdi).

Study design: The experiment was designed with six boron treatments, arranged in a randomized complete block design (RCBD) with three replications.

Place and Duration of Study: The field trial was conducted at Bangladesh Agricultural University (BAU) farm, Mymensingh during 27 November 2010 to 24 March 2011.

Methodology: The B treatments were (i) B control, (ii) soil application of B, (iii) seed priming into boric acid solution, (iv) foliar spray of B at primordial stage, (v) foliar spray of B at booting stage and (vi) foliar spray of B at primordial and booting stages. Boric acid was used as a source of boron. The rate of B for soil application was 1.5 kg B 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. Every plot received 115 kg N, 25 kg P, 75 kg K and 15 kg S per hectare from urea, TSP, MoP and gypsum, respectively.

Results: The treatment receiving foliar spray of B at both primordial and booting stages or only at booting stage of the crop performed the highest yield (3625 kg ha^{-1}) which was statistically identical with the yield recorded with foliar spray of B at primordial stage only or with soil application of B; all the yields were significantly higher over the yield of seed priming or control treatment. The B control treatment had the lowest grain yield (2600 kg ha^{-1}) which was significantly lower than the yield observed with the seed priming treatment.

Conclusion: Wheat yield was affected due to grain set failure induced by boron deficiency and it was possible to overcome this element deficiency by soil application of boron at 1.5 kg ha^{-1} or foliar application of 0.4% boric acid solution at booting stage of crop.

Keywords: Boric acid; Foliar spray; Wheat yield

INTRODUCTION

Wheat in the world ranks first both in area and production and in Bangladesh it ranks second after rice. About the two-thirds people of the globe live 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]. The yield of wheat is low in Bangladesh and also in many countries, and boron deficiency could be a major reason for it. 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 [2]. Boron Boron deficiency causes male sterility in wheat, as observed in China [3], India [4], Thailand [5], Nepal [6] and Bangladesh [7]. Boron deficiency is more evident in dry land crops, e.g. mustard, wheat, chickpea and less in rice crop. 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^{-1} in Bangladesh [8]. Cooke [9] suggests as general guidelines for B fertilization 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, boron fertilization needs a careful thought. Efficiency of B application depends on the time and method of B application.

Jolanta Korzenniows [10] from a field trial reported that foliar application of boron resulted in a significant increase of grain yield of four out of ten wheat varieties. 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 [11]. Marphy and Walsh [12] 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 [13]. .Reproductive growth (flowering, fruit and seed set) is more sensitive to boron deficiency compared to vegetative growth [14]. 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. In foliar application,the amount of boron fertilizer would be at least five times less. Debnath et al. [15] conducted a field trail at BAU farm, Mymensingh during 2009-2010 wheat season using varying rates of soil B application and noted a significant response of grain yield to the added boron. With the above understanding, a study was done to evaluate the effect of foliar application of boron on the grain set and yield of wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

The experiment was carried out during 2010-2011 wheat season at Bangladesh Agricultural University (BAU) farm, Mymensingh. The experimental field is located at 24.75°N latitude and 90.50°E longitude at a height of 18m above the mean sea level. It was a medium high land and falls under the AEZ 9 (Old Brahmaputra Floodplain). The soil was Sonatala silt loam, a member of Aeric Haplaquept. It belongs to the order Inceptisol having only few horizons, developed under aquatic moisture regime. Physical and chemical characteristics of the soil are presented in Table 1.

Table 1. Physical and chemical characteristics of the soil

Characteristics	Content	Interpretation
Soil texture	Sand–20.4%, Silt – 68.0%, Clay – 11.6%	Silt loam
pH (soil: water = 1:2.5)	7.30	Near neutral
Organic matter (%)	0.81	Very Low
Total N (%)	0.06	Low
Available P (mg kg^{-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^{-1})	0.84	Low
Available B (mg kg^{-1})	0.15	Low

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

T_1 = Control

T_2 = Soil application of 1.5 kg B ha^{-1} (designated as SA)

T_3 = Seed priming (wheat seed soaked in 0.1% boric acid solution for 10 hours before sowing - designated as SP)

T_4 = Foliar spray of 0.4% boric acid solution at primordial stage of crop growth (designated as FS-p)

T_5 = Foliar spray of 0.4% boric acid solution at booting stage of crop growth (designated as FS-b).

T_6=Foliar spray of 0.4% boric acid solution at primordial and booting stages (designated as FS-pb).

The treatments were distributed to the field following the principle of randomized complete block design (RCBD), with three replications. The crop variety was Shatabdi, developed by the Bangladesh Agricultural Research Institute (BARI). 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 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 dose of urea was applied after 30 days of sowing (crown root stage) and the third split after 55 days (booting stage). For foliar spray treatments, boric acid solution was sprayed at 55 and 75 days after sowing to represent primordial and booting stages of crop, respectively.

Wheat was sown on 27 November 2010 and harvested on 24 March 2011. The cultural practices such as weeding and insecticide spray were done as and when required. Two irrigations were provided after 25 and 55 days of 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 insecticide.

As evaluation of the treatment effects, data were collected in terms of yield and its components. The yield data included grain and straw yields, and the growth and yield components included plant height, number of tillers $plant^{-1}$, spike length, number of spikelets $spike^{-1}$, number of 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 viz.plant height, number of tillers $plant^{-1}$ and spike length were also recorded. The grain and straw yields were recorded on each plot.

The analysis of variance (ANOVA) for all the plant parameters was done following the principle of F-statistics. Mean comparison of the treatments were adjudged by the Duncan's Multiple Range Test [16]. Correlation statistics was performed to examine the interrelationship among the plant characters under study.

RESULTS AND DISCUSSION

Application of boron had significant positive effect on grain yield, spikelets $spike^{-1}$, grains $spike^{-1}$ and 1000-grain weight. The other plant characters remained unaffected by boron application, whether added to soil, seeds or plant as foliar spray. The results are discussed below.

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 lowest plant height was observed with the B control (90.2 cm). 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.

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 tillers plant^{-1}. Per plant tillers varied from 2.83-3.60. All the B treatments produced higher number of tillers plant^{-1}, compared to B control.

Spike length

Like plant height and tillers, 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 9.10 cm in T_1 (control) to 9.84 cm in T_5 treatment (foliar spray of B at booting stage). Mandal and Das [8] in India also observed that B application to soil at the rate of 10, 15 and 20 kg ha^{-1} failed to show significant effect on spike length of wheat.

Table 2. Effects of different B treatments 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 a	2.83 a	9.10 a
T2: SA	95.9 a	3.60 a	9.83 a
T3: SP	93.8 a	3.06 a	9.54 a
T4: FA-p	97.1 a	3.10 a	9.71 a
T5: FA-b	94.1 a	3.16 a	9.84 a
T6: FA-pb	93.8 a	3.23 a	9.41 a
Level of significance	NS	NS	NS
CV (%)	3.6	14.0	3.4
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 of 1.5 kg boron ha^{-1}; SP = Seed priming into 0.1% boric acid solution for 10 hours; FS-pb = Foliar spray of 0.4% boric acid solution at primordia and booting stages of crop.

Spikelets spike^{-1}

The number of spikelets spike^{-1} varied significantly due to boron treatments (Table 3). Except T_3 (seed priming), all other methods of boron application 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 from seed priming (T_3).

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.

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 44.5 (B control) to 54.7 (foliar spray at primordial and booting stages of the crop). However, foliar application of B either at booting stage or at primordial and booting stages of the crop statistically produced similar grain weight. The least 1000-grain weight was recorded by B control treatment.

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	15.4 d	15.2 c	44.5 d
T2: SA	17.0 ab	41.7 a	48.7 bc
T3: SP	15.7 cd	31.5 b	47.8 c
T4: FA-p	17.2 a	39.6 a	48.6 bc
T5: FA-b	16.4 bc	39.6 a	51.6 ab
T6: FA-pb	16.1 bd	38.2 a	54.7 a
Level of significance	*	**	**
CV (%)	2.7	9.7	3.7
S.E. (±)	0.200	10.94	3.275

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

Grain yield

The grain yield of wheat (cv. Shatabdi) was significantly influenced by boron application (Table 4). Significantly higher grain yield was obtained in soil added B treatment and the next higher yield was observed with seed priming of B treatment. The grain yield ranged from 2600 to 3625 kg ha^{-1} over the treatments. Yield benefits due to T_2, T_3, T_4, T_5 and T_6 treatments were 27.5%, 15.6%, 26.5%, 30% and 30% yield increase over control, respectively. The soil and foliar B treatments gave statistically similar yield which was significantly higher than the seed priming treatment and again the seed priming treatment significantly differed from the control treatment. The available B content of soil under study was 0.15 mg kg^{-1} which as per National Fertilizer Recommendation Guide [17] was inadequate to support normal plant growth. Thus, the experiment showed a good correlation between soil test value and crop response. The higher yield of wheat as obtained with B treatment agrees well to the findings, as reported in Bangladesh [10, 11, 13], India [8], Nepal [9], China [7] and Thailand [6].

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^{-1}) was observed with B control and the highest yield (6388 kg/ha) with B application at primodia and booting stages of crop. Yield advantages due to T_5 and T_6 treatments were 11.8% and 12.0% increase over control, respectively.

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
T_1: Control	2600 c	-	5625	-
T_2: SA	3583 a	27.5	5676	0.9
T_3: SP	3083 b	15.6	5870	4.1
T_4: FA-p	3533 a	26.5	6011	6.4
T_5: FA-b	3625 a	30.0	6375	11.8
T_6: 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.

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), The straw yield was positively correlated with plant height and spike length only. There was no significant 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. Thus it appears 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 plant characters under study (n=18)

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

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

CONCLUSION

Wheat yield is markedly affected due to grain set failure induced by boron deficiency. This element deficiency can be overcome by boron fertilizer use. Boron fertilizer can be effectively used through foliar spray at booting stage of crop and also through its application to soil before sowing of crop (wheat).

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