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Determining optimum rate of boron application for higher yield of wheat in Old Brahmaputra Floodplain soil

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Abstract

The effect of different rates of boron application on wheat cv. Bijoy was studied through a field experiment at Bangladesh Agricultural University (BAU) farm, Mymensingh during 2009-10 rabi season. The BAU farm belongs to Old Brahmaputra Floodplain agroecological zone (AEZ 9). Texturally the soil was silt loam, with 7.2 pH, 0.81% organic matter and 0.15 mg kg⁻¹ available boron content. The experiment was laid out in a randomized complete block design with five boron rates and four replications. Boron rates were 0, 0.75, 1.5, 2.25 and 3.0 kg ha⁻¹, with boric acid as a source. Every plot received blanket doses of 115 kg N, 25 kg P, 75 kg K and 15 kg S ha⁻¹ from urea, TSP, MoP and gypsum, respectively. Treatment receiving B @ 2.25 kg ha⁻¹ produced the highest grain yield (4.22 t ha⁻¹) which was statistically identical with that obtained with 1.75 kg B ha⁻¹. However, the crop response curve showed 1.90 kg ha⁻¹ to be the optimum boron rate for the maximization of wheat yield. The lowest grain yield (2.84 t/ha) was recorded with control treatment. There was a positive relationship between grain yield and number of grains spike⁻¹. Boron had significant influence on N, P, K, S and B uptake by the crop which, in deed, was more influenced by crop yield and less by nutrient concentration, except N and B uptake where concentration had more influence than yield.

Keywords: Boron, Floodplains, Wheat

Introduction

Wheat, next to rice, is the second most important cereal crop in Bangladesh. Despite the constraint that winter in Bangladesh is short and mild compared to the traditional wheat growing countries in the world, the crop has nicely adapted to this country's climate. In order to meet the food deficit in Bangladesh and to cope with the food demand for the increasing population, wheat cultivation deserves due attention.

With advancement of time, new nutrient deficiency has arisen in Bangladesh soils which is mainly due to the increasing cropping intensity, accompanied with the use of modern varieties. Before 1980, deficiencies of N, P and K were the major nutrient deficiency in crops. During early 1980s, S and Zn deficiencies were recognized and in 1990, B deficiency was reported on some soils and crops.

The yield of wheat in Bangladesh is low which can be attributed to boron deficiency (Jahiruddin *et al.*, 1992a,b, 1995). Rerkasem *et al.* (1993) found that in B deficient wheat, the pollen did not accumulate starch and the nuclei, when present, was abnormal. Boron requirement may vary among plant species and also within the genotype of a species (Rerkasem, 2002). Boron deficiency causes grain sterility in wheat as reported by Li *et al.* (1978) in China, Mandal and Das (1988) in India, Rerkasem *et al.* (1989) in Thailand, Sthapit (1988) in Nepal and Jahiruddin *et al.* (1992a) in Bangladesh. Reproductive growth, especially flowering, fruit and seed set are more sensitive to B deficiency than vegetative growth (Noppakoonwong *et al.*, 1997).

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 (Gupta *et al.*, 1985). As general guidelines for B fertilizer recommendations, Cooke (1982) 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 B, deficiency may appear and insurance dressings are to be considered; when it is more than 1.0 mg kg⁻¹ B, deficiency is unlikely and B treatment is not necessary; and when it is 3-5 mg kg⁻¹ B, crops may be poisoned from excess B. Thus, a careful and judicious application of boron is necessary for achieving higher and sustainable crop yield.

The present investigation was, therefore, undertaken to find out an optimum rate of boron application in soil to obtain higher and sustainable yield of wheat.

Materials and Methods

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) farm, Mymensingh during 2009-10 rabi season. Experimental field was a medium high land under the AEZ 9, Old Brahmaputra Floodplain (UNDP and FAO, 1988). Texturally the soil was silt loam. It contained 7.2 pH, 0.81% organic matter, 0.06% total N, 7.29 mg kg⁻¹ available P, 0.06 c mol kg⁻¹ available K, 10.0 mg kg⁻¹ available S, 0.84 mg kg⁻¹ available Zn and 0.15 mg kg⁻¹ available B contents. The crop variety was Bijoy (BARI Gom-23). The experiment was laid out in a randomized complete block design (RCBD) with four replications, each plot being 4m × 4m. There were five boron rates- 0, 0.75, 1.50, 2.25 and 3.00 kg B ha⁻¹. Besides boron, every treatment had received 115 kg N, 25 kg P, 75 kg K and 15 kg S ha⁻¹. Urea, TSP, MoP, gypsum and boric acid were used as sources for N, P, K, S, and B, respectively. The one-third dose of urea and full dose of all other fertilizers were applied as basal to all 20 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 56 days (booting stage). Wheat seeds were sown continuously in 20 cm apart lines at a rate of 125 kg ha⁻¹. Two irrigations were provided during whole crop growth, one 24 days and other 55 days after sowing. Other intercultural operations viz. weeding and insecticide spray were made whenever required. The crop was harvested at maturity. Data on the yield and yield contributing characters were recorded. Grain and straw samples from every plot were analyzed for N, P, K, S and B levels. Nutrient uptake was calculated using the data of grain and straw yields and their nutrient concentration. All data were statistically analyzed using MSTAT computer software program. Mean comparisons of the treatments were made by the Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Effects of boron application on growth, yield components, yield, and nutrient concentration and uptake was significant in most cases. Results are presented in Tables 1-4 and Fig. 1.

Effects on the growth and yield components of wheat

Boron application had no significant effect on the plant height of wheat cv. Bijoy (Table 1) showing a range of 89.7-97.3 cm over the five B treatments. The spike length significantly varied with B treatments, with the highest length (11.6 cm) recorded in 2.25 kg ha⁻¹ B treatment and the lowest length (10.3 cm) in B control. The number of effective tillers plant⁻¹ did not respond significantly to the B treatments. The number of spikelets spike⁻¹ also did not vary significantly due to different B rates (Table 1). Boron treatments resulted in a significant improvement in the number of grains spike⁻¹ (Table 1), showing a range of 29.8 to 38.5. Treatment receiving 2.25 kg B ha⁻¹ had the highest number of grains spike⁻¹ and the B control had the lowest number. There was no significant effect of boron application on 1000-grain weight which was 35.8 to 36.0 g across the treatments (Table 1).

Table 1. Effects of different rates of boron application on growth, yield and yield contributing characters of wheat

Boron rates	Plant height (cm)	Spike length (cm)	Effective tillers plant ⁻¹	Spikelets spike ⁻¹	Filled grains spike ⁻¹	1000-grain weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
B control	89.7	10.4 b	4.55	16.6	29.8 c	35.8	2.84 c	4.35
0.75 kg B ha ⁻¹	91.4	10.3 b	3.65	16.0	30.3 c	36.0	3.47 b	4.40
1.5 kg B ha ⁻¹	92.5	10.9 ab	3.30	16.6	33.8 b	36.0	4.14 a	4.44
2.25 kg B ha ⁻¹	97.3	11.6 a	4.00	17.2	38.5 a	36.0	4.22 a	4.56
3.0 kg B ha ⁻¹	87.2	10.3 b	3.95	16.3	33.1 b	35.9	3.63 b	4.40
CV(%)	3.58	5.92	22.5	4.35	5.12	2.68	3.61	1.19
SE (±)	NS	0.32	NS	NS	0.85	NS	0.01	NS

Values in a column having same letter do not differ significantly at 5% level by DMRT.

NS= Not significant, CV= Coefficient of variation, SE= Standard error of means

Effects on the grain and straw yields of wheat

The grain yield of wheat (cv. Bijoy) was significantly influenced by boron application (Table 1). The grain yield increased progressively up to 2.25 kg B ha⁻¹ and thereafter declined at higher rate (3 kg B ha⁻¹). The highest yield (4.22 t ha⁻¹) recorded with 2.25 kg B ha⁻¹ application was statistically identical with that (4.14 t ha⁻¹) noted with 1.5 kg ha⁻¹ B rate. The B control gave the lowest grain yield (2.84 t ha⁻¹). Yield benefits over control due to boron application @ 0.75, 1.50, 2.25 and 3.00 kg B ha⁻¹ were found as 22.2, 45.8, 48.6 and 27.8 %, respectively (Table 1).

An attempt has been made to fit the yield data to the quadratic equation- $y = a + bx + cx^2$. The equation thus obtained was $y = 2.7611 + 1.465x - 0.3848x^2$ (Fig. 1). From the equation, an optimum B rate that has maximized yield has been computed following the procedure, as outlined by Gomez and Gomez (1984).

Rate of boron that maximizes yield: $By = \frac{-b}{2c}$

Where b and c were the estimates of the regression coefficient. The *By* value was estimated as 1.90 kg ha⁻¹.

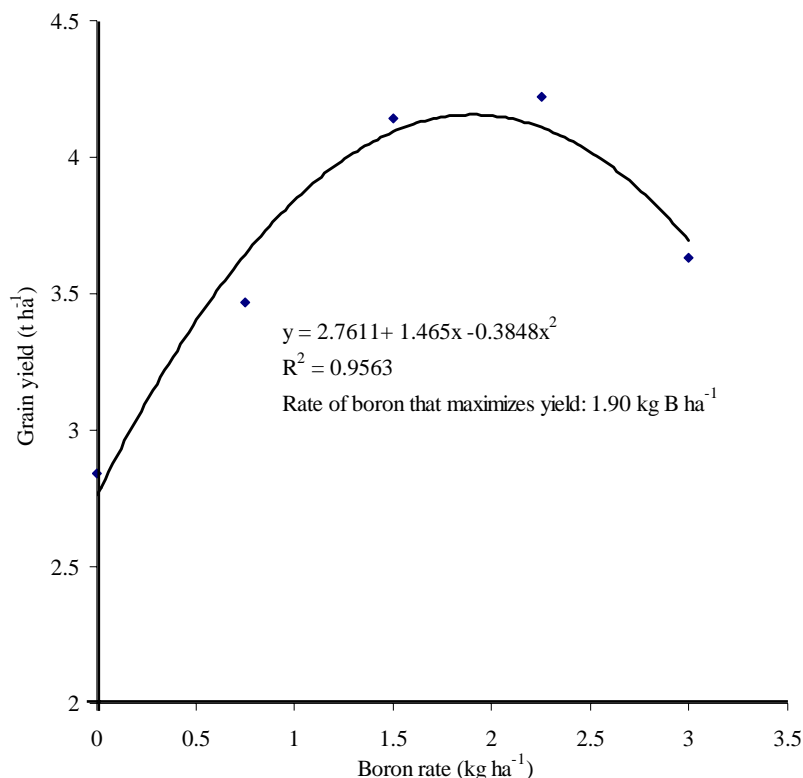


Fig.1 Relationship between grain yield and boron rates

The soil B content (0.15 mg kg⁻¹ hot water extractable B) of wheat field 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 Ahmed *et al.* (2008) and Kamal *et al.* (2009) in Bangladesh, Rerkasem *et al.* (1989) in Thailand, and Mukherjee and Bhowmik (2008) in India.

The straw yield of wheat was not influenced by the B treatments (Table 1). The highest straw yield (4.56 t ha⁻¹) was obtained with 2.25 kg ha⁻¹ B treatment and the lowest (4.35 t ha⁻¹) with control.

Grain yield is a complex character that results from contribution of several plant parameters. The grain yield was positively influenced by spike length ($r=0.48$; $P<0.05$), filled grains spike⁻¹ ($r=0.89$; $P<0.01$) and 1000-grain weight ($r=0.59$; $P<0.01$) (Table 2). There was a significant and positive correlation between grain and straw yields of wheat ($r=0.69$; $P<0.01$). This result otherwise indicates that the grain set of wheat is interrupted by boron deficiency and it is possible to overcome this problem by B application to soil.

Table 2. Correlation matrix among different plant parameters, grain yield and straw yield of wheat (n=20)

Variables	Plant height	Spike length	Spikelets spike ⁻¹	Filled grains spike ⁻¹	Effective tillers hill ⁻¹	1000-grain weight	Grain yield	Straw yield
Plant height	1							
Spike length	0.80**	1						
Spikelets spike ⁻¹	0.49*	0.68**	1					
Filled grains spike ⁻¹	0.64**	0.63**	0.50*	1				
Effective tillers hill ⁻¹	0.03	0.01	0.03	0.16	1			
1000-grain weight	0.40	0.40	0.19	0.58**	0.21	1		
Grain yield	0.44	0.48*	0.42	0.89**	0.11	0.59**	1	
Straw yield	0.53*	0.63**	0.49**	0.66**	0.23	0.45*	0.70**	1

*, $P<0.05$ **, $P<0.01$

Effects on the nutrient concentration of wheat

The N concentration of grain remained unaffected by B treatments (Table 3) but in straw the N concentration markedly varied. The N concentration in grain varied from 1.94-2.20% and that in straw from 0.56-0.70%, the lowest N concentration being recorded with B control for both plant parts. Boron application had significant effect on the P concentration of grain and no effect on the P concentration of straw (Table 3). The grain P concentration ranged between 0.34-0.43% and straw P 0.03-0.04%. The highest P concentration both in grain and straw was obtained with B treatment @ 2.25 kg ha⁻¹ and the lowest P concentration was recorded with B control. The K concentration of wheat grain significantly varied with B treatments (Table 3). The grain K concentrations over the treatments were 0.39-0.47%. The highest grain K concentration (0.47%) was noted in 3.0 kg ha⁻¹ B treatment and the lowest grain K concentration in B control. The straw K concentration was also affected by B application (Table 3), showing the highest K concentration (1.95%) in 3.0 kg B ha⁻¹ treatment and the lowest straw K in control (1.69%). The S concentration of both straw and grain was significantly influenced by the B treatments (Table 3), the highest grain S concentration being recorded by 2.25 kg ha⁻¹ B rate and the highest straw S concentration by 3.0 kg B ha⁻¹, with the lowest S concentrations recorded by B control. The grain B concentration was significantly influenced by the B treatments (Table 3). Comparing the effects of various rates of B application, the 2.25 kg ha⁻¹ B rate showed the highest B concentration (16.1 µg g⁻¹) in grain and the B control treatment did the lowest B concentration (10.1 µg g⁻¹). The grain B concentration in all four B treatments was significantly higher than that in B control. The straw B concentration was also affected by B application (Table 3). The highest and lowest straw B concentrations were 18.1 and 13.1 µg g⁻¹ due to 2.25 kg B ha⁻¹ and B control, respectively.

Table 3. Effects of different rates of boron application on the N, P, K, S and B concentrations of wheat grain and straw

Boron rates	N (%)		P (%)		K (%)		S (%)		B ($\mu\text{g g}^{-1}$)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
B control	1.94	0.56 d	0.34 b	0.03	0.39 c	1.69 c	0.07 c	0.06 c	10.1 e	13.1 e
0.75 kg B ha ⁻¹	2.12	0.60 c	0.38 b	0.03	0.42 bc	1.70 c	0.08 b	0.07 bc	13.1 d	15.0 c
1.5 kg B ha ⁻¹	2.17	0.63 b	0.39 ab	0.03	0.41 c	1.78 b	0.08 ab	0.07 b	15.1 b	15.9 b
2.25 kg B ha ⁻¹	2.20	0.70 a	0.43 a	0.04	0.44 b	1.81 b	0.09 a	0.07 b	16.1 a	18.1 a
3.0 kg B ha ⁻¹	2.15	0.63 b	0.39 ab	0.03	0.47 a	1.95 a	0.08 ab	0.08 a	14.2 c	14.8 d
CV(%)	5.71	2.86	9.09	25.8	4.05	1.83	4.40	4.55	2.03	0.5
SE (\pm)	NS	0.01	0.02	NS	0.01	0.02	0.01	0.01	0.14	0.04

Values in a column having same letter do not differ significantly at 5% level by DMRT.

NS= Not significant, CV= Coefficient of variation, SE= Standard error of means

Effects on the nutrient uptake by wheat

The N uptake by wheat grain was significantly influenced by the different B treatments (Table 4). The N uptake by grain varied from 55.1-92.8 kg ha⁻¹, the highest N uptake was recorded by 2.25 kg ha⁻¹ B treatment and the lowest N uptake by the B control. Similar result was observed in straw N uptake as well as total N uptake by the crop. The P uptake by both grain and straw significantly differed with B treatments. In both cases, the lowest P uptake was found in B control and the highest P uptake in 2.25 kg ha⁻¹ B treatment. The total P uptake was also significantly and positively influenced by the boron treatments (Table 4). The K uptake by grain and straw also significantly increased due to different rates of B application (Table 4). The K uptake by grain ranged from 11.1-18.5 kg ha⁻¹, the highest K uptake being noted with 2.25 kg B ha⁻¹ and the lowest with B control. The K uptake by straw varied between 73.4 and 85.7 kg ha⁻¹. The treatment receiving B @ 3.0 kg ha⁻¹ demonstrated the highest K uptake by straw and the treatment receiving no B dose exhibited the lowest K uptake. The S uptake by grain and straw was significantly influenced by B application (Table 4). In case of grain S uptake, the highest uptake was found in 2.25 kg B ha⁻¹ treatment and the lowest S uptake in B control. On the other hand, the highest and lowest straw S uptake was observed in 3.0 kg B ha⁻¹ and B control, respectively. As expected, B application had significant and positive effect on the B uptake by grain and straw (Table 4). In both cases, the lowest B uptake was found in B control and the highest in treatment having B @ 2.25 kg ha⁻¹.

Table 4. Effects of different rates of boron application on the N, P, K, S and B uptake of wheat

Boron rates	N uptake (kg ha ⁻¹)			P uptake (kg ha ⁻¹)			K uptake (kg ha ⁻¹)			S uptake (kg ha ⁻¹)			B uptake (g ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
B control	55.1 c	24.4 d	79.5 c	9.85 c	1.20 b	11.1 c	11.1 d	73.4 d	84.5 c	1.95 d	2.60 d	4.55 e	28.8 d	57.0 d	85.7 d
0.75 kg B ha ⁻¹	73.6 b	26.4 c	100.0b	13.2 b	1.21 b	14.4 c	14.6 c	74.7 d	89.3 c	2.78 c	2.80 c	5.58 d	45.5 c	65.8 c	111.3 c
1.5 kg B ha ⁻¹	89.8 a	28.1 b	117.9a	16.1ab	1.33ab	17.4 b	17.0 b	79.0 c	96.0 b	3.31 b	2.98 b	6.29 c	62.5 a	70.4 b	132.9 b
2.25 kg B ha ⁻¹	92.8 a	31.6 a	124 a	18.1 a	1.82 a	19.9 a	18.5 a	82.4 b	101 a	3.73 a	3.07 b	6.80 a	67.9 a	82.5 a	150 a
3.0 kg B ha ⁻¹	77.9 b	27.8 b	106 b	14.0 b	1.32ab	15.4 b	17.1 b	85.7 a	103 a	3.03 b	3.41 a	6.44 b	51.5 b	64.9 c	116 c
CV(%)	8.00	3.00	5.56	10.6	26.3	10.8	5.53	1.89	2.03	6.25	3.07	3.53	3.84	1.10	1.50
SE (\pm)	2.93	0.41	2.80	0.71	0.19	0.80	0.41	0.75	0.96	0.09	0.05	0.10	0.93	0.38	0.87

Values in a column having same letter do not differ significantly at 5% level by DMRT.

NS= Not significant, CV= Coefficient of variation, SE= Standard error of means

Conclusion

The Old Brahmaputra Floodplain soil (AEZ 9) is deficient in boron and thus, to meet this element deficiency and ensure higher wheat yield, the soil needs to be supplied with boron @ 1.90 kg ha⁻¹.

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