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Assessment of critical limit of available boron for rice in old alluvial zone of West Bengal

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ABSTRACT

A pot culture experiment was conducted on rice to study the critical limit of boron in soils of old alluvial zone of West Bengal. The hot water soluble (HWS) boron in these soils was found to be positively and significantly correlated with organic carbon, clay content and per cent dry matter yield of rice, boron concentration in plant tissues and B uptake by shoots. A negative relationship was also observed between WHS boron and silt and sand content. The critical concentration of soil available boron and plant tissues boron was worked out to 0.38 and 15.0 mg kg^{-1}, respectively. Soil containing available B below the critical limit responded appreciably to B fertilization. A negative response to boron application was also observed at its higher level. The average dry matter yield increases with increasing level of boron application up to 1.5 mg kg^{-1}in boron deficient soils. The response to boron application in rice on boron deficient soils was found to be 52.5%.

Key words: *boron, critical limits, old alluvial zone, rice*

Rice is one of the most important food crop and a primary food source for more than one third of world's population (Prasad *et al*., 2010). In India, West Bengal is one of the leading states in rice cultivation. Productivity of rice depends upon balance application of nutrients. Farmer of this region having the apathy to use micronutrients in their farming system. As a result, soil becomes poor in micronutrients. Boron (B) is one of the seventeen elements essential for plant growth (Joham, 1986) and is directly or indirectly involved in many plant metabolic functions (Blevins and Lukaszewski, 1998). The application of boron through different sources either through soil or foliar found to be beneficial in simulating plant growth and in increasing yield of crops such as black gram (Singh *et al*., 2002), rice (Debnath and Ghosh, 2011) and wheat (Sakal *et al*., 2002).

Widespread boron deficiency has been reported in soils of humid region of the world (Datta *et al*., 1998). The ranges between deficiency and toxicity of boron are quite narrow and that an application of boron can be extremely toxic to plant at concentration only slightly above the optimum (Das, 2003). This emphasised the need for careful appraisal of boron status through soil and plant test for judicious use of boron fertilizer. The apparent and latent symptoms of B deficiency have been recorded on rice and other field crops including vegetables crops grown in soils of old alluvial zone of West Bengal. Preliminary studies have indicated B deficiency in soils of West Bengal (Saha, 1992) but no information was available regarding the threshold value of available B in these soils. Therefore, the present investigation was planned to study the critical concentration of B in soils and rice crop which is widely grown in West Bengal for making boron application more rational.

MATERIALS AND METHODS

Twenty four soil samples in bulk from plough layer (0-20 cm) were collected from different locations of old alluvial zone. This zone comprised of three districts viz, Malda, Uttar Dinajpur and Dakhin Dinajpur of West Bengal. These soils belong to order Inceptisols and Entisols. The collected soil samples were separately air dried, ground and passed through 2 mm size sieve for laboratory analysis. Particle size distribution was done by the standard Bouyoucos hydrometer method (Day, 1965). Soil pH was determined by glass electrode with calomel as standard (Jakson, 1973). Organic carbon was estimated by wet digestion method of Walkey and Black (Jackon, 1973). The cation exchange capacity was determined by leaching the soil with 1N NH_4^+OAC and subsequently displacing the adsorbed NH_4^+ following the methods of Schollenberger and Simon (1945). The soils samples were extracted for available B by the method of Wear (1965). Activated charcoal was used so as to obtain colourless extract. Boron was estimated in clear filtrate colorimetrically using azomethine–H-method (Wolf, 1971).

A pot culture experiment was conducted in a greenhouse in polythene lined pots. The polythene lining was rinsed in 0.1N HCI followed by deionized water. Four kg of each soil was transferred into each pot. Recommended doses of N, P_2O_5, and K_2O @ 50, 25 and 25 mg kg^{1}, respectively were applied as reagent grade i.e. Urea, KH_2PO_4 and KCl. Three 21 days old rice seedling (variety-IR 36) were transplanted in each pot. Boron was applied @ 0, 0.5, 1 and 1.5 mg kg^{1} soil as reagent grade borax after 7 days of transplanting of rice seedling. Each treatment was replicated thrice in completely randomized design. Watering with deionized water and intercultural operations like weeds control and plant protection measures were adopted uniformly in each pot as and when required. Above ground portion of rice plant were harvested after 30 days of transplanting and washed in acidified solution, rinsed with deionized water, dried at 65 ^{0}C in a hot air oven and dry-matter yield was recorded. The dried rice plant and dried 3rd leaf samples of each pot were separately powdered in a warring stainless steel grinder. Dry

Table 1. Physico-chemical properties and hot water soluble boron content of the study area

Location		Physico-chemical properties							WHS boron (mg kg^{-1})
Sampling Site	District	pH	Organic Carbon (g kg^{-1})	Sand (%)	Silt (%)	Clay (%)	Textural Classes	CEC [Cmol(p$^+$) kg^{-1}]	
Chopra	Uttar Dinajpur	5.8	6.6	27	31	42	C	15.8	0.62
Islampur	,,	6.4	5.9	36	46	18	L	12.5	0.38
Karandighi	,,	6.0	4.2	48	36	16	L	10.2	0.24
Raigunge	,,	6.2	3.8	40	40	20	L	14.5	0.30
Kaliaganj	,,	6.3	4.5	20	50	30	CL	12.5	0.40
Hemtabad	,,	6.1	4.1	28	52	20	SiL	8.5	0.25
Itahar	,,	5.9	3.9	36	50	14	L	9.5	0.24
Goalpukur	,,	7.6	4.2	34	43	23	L	8.4	0.33
Old Malda	Malda	5.8	2.7	35	50	15	L	6.8	0.18
Kaliachak	,,	7.6	6.3	21	48	31	CL	12.6	0.62
Nalpur	,,	7.5	6.1	18	52	30	SiCL	12.0	0.42
Gajole	,,	6.5	5.4	38	39	23	L	11.0	0.32
Sultanganj	,,	6.0	4.5	26	54	20	SiL	9.7	0.38
Habibpur	,,	6.2	6	27	55	30	SiCL	10.1	0.41
Manikchak	,,	5.9	6.8	30	42	28	CL	16	0.70
English Bazar	,,	7.4	4.4	35	44	21	L	14	0.35
Kumarganj	Dakhin Dinajpur	5.9	5.2	30	40	30	L	15	0.43
Tapan	,,	6.2	6.7	48	26	26	CL	15.5	0.72
Balurghat	,,	6.4	4.3	37	39	26	L	11.0	0.39
Hili	,,	5.8	5.2	25	51	24	SiL	14.0	0.46
Gangarampur	,,	6.5	4.8	37	36	27	L	13.5	0.36
Kushardi	,,	6.3	3.5	30	54	16	L	8.9	0.27
Harirampur	,,	6.2	2.8	36	47	17	L	9.0	0.18
Banshihari	,,	6.1	6.4	36	42	22	L	14.8	0.65
Mean		6.3	4.92	32.40	44.45	23.70		11.90	0.39
Range value		5.8-7.6	2.7-6.8	18-48	26-55	14-42		6.8-16	0.18-0.72

CL=Clay loam, SiCL=Silty clay loam, L=Loam, SiL=Silt loam, C=Clay.

powdered plant samples were ashed in a muffle furnace at 600 ºC and then ash was extracted in 10 ml 0.36 N H_2SO_4 for 1 hr at room temperature. The concentration of B was determined colorimetrically using azomethine –H - method (Wolf, 1971). The critical limit of boron in soil and plant was determined by plotting percentage yield against soil available B and plant tissue B concentration, respectively, using the procedure of Cate and Nelson (1965). Bray's per cent yield of rice was calculated as follows:

Bray's per cent yield=

$$\frac{\textit{Yield without boron treatment}}{\textit{Yield at optimum boron treatment}} \times 100$$

Simple correlation analysis was carried out to establish the relationships between the available B and soil properties.

RESULTS AND DISCUSSION

The organic carbon, clay content, CEC and pH are widely considered to be important factors for determining the availability of boron in soils and plants. The data of HWS boron and relevant physical and chemical properties of the soils of old alluvial zone of West Bengal are presented in table 1. The data revealed that soil texture varied from sandy loam to clay loam. The range value of pH was 5.8 – 7.6 with a mean of 6.3. The result indicates that soils are mostly in slightly acidic to neutral in reactions. The organic carbon status of soil samples ranged from 3 to 9.5 g kg^{-1} with a mean value of 4.92 g kg^{-1}. (Debnath *et al*., 2009). In general, soils were low in organic carbon and about 60 per cent soils were found to be deficient in organic carbon. The range value of cation exchange capacity was 6.8 to 16 cmol (p+) kg^{-1} with mean value of 11.9 cmol (p+) kg^{-1}. The result is in agreement with earlier works of Chaudhury and Debnath (2008) and Thakur *et al*. (2011).

The critical limit in plant refers to a level at or below which plant either develops deficiency symptoms or causes reduction in crop yield as compared to optimum. The available B in these soils ranged between 0.18 to 0.72 mg kg^{-1} with mean value 0.39 mg kg^{-1} (Yadav and Meena, 2009) (Table 1). The percentage to dry matter yield of rice ranged from 50.9- 110.7 with a mean value 82.4. The value of B concentration in 3rd leaf of rice crop, total B in entire shoot and B uptake by rice shoot in no B applied pots were 8-24 mg kg^{-1}, 11-28 mg kg^{-1} and 59.4-414.4 µg pot^{-1} with respective mean value of 14.6 mg kg^{-1}, 20 mg kg^{-1} and 209.2 µg pot^{-1} (Table 2). The plot of Bray's per cent yield against soil available B and plant tissue B revealed 0.38 and 15.0 mg kg^{-1}, respectively as the critical concentration of B in soils and plant (Fig. 1 and 2). These values are close to critical level of B (0.45 mg kg^{-1}) as observed by Dwivedi *et al*. (1993). However, critical limit of hot water B and plant tissue B was 0.52 mg kg^{-1} soil and 23.5 mg kg^{-1} reported by Sakal *et al*. (1987) for black gram in 24 recent alluvial soils of Bihar, below which appreciable responses to B application were observed.

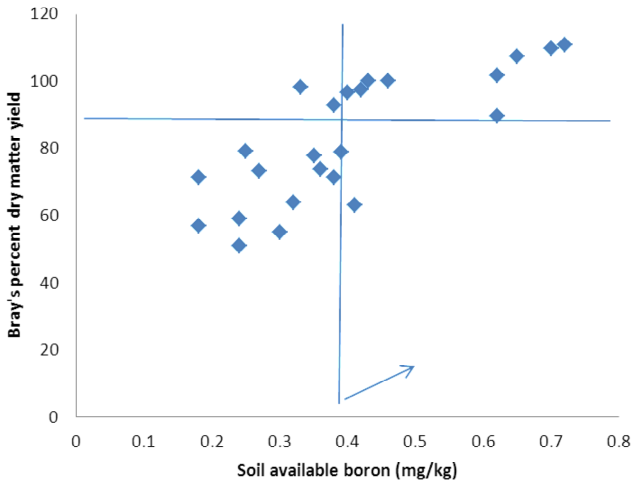

Fig. 1. Scatter diagram of hot water soluble boron Vs. percent dry matter yield of rice grown in soils of old alluvial Zone of West Bengal

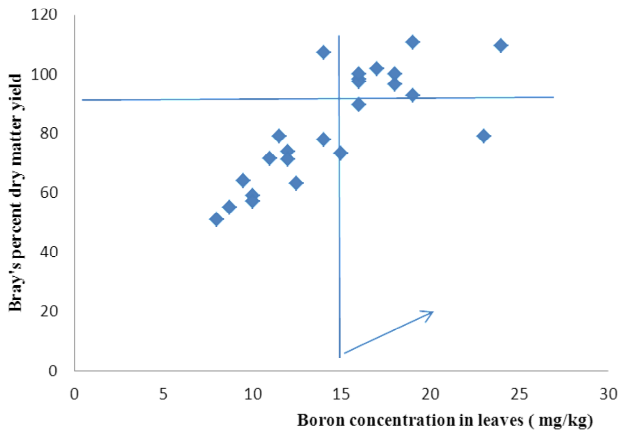

Fig. 2. Scatter diagram of third leaf boron Vs. percent dry matter yield of rice grown in soils of old alluvial zone of West Bengal

Table 2. Effect of Boron application on dry-matter yield, boron concentration in leaf and shoots and boron uptake by rice

Sl No	HWS boron (mgkg-1)	Shoot weight (g pot $^{-1}$) Application of B (mg kg^{-1} soil)				Bray's per cent yield at optimum B level	Total B in the 3rd rice leaf of no B pots (mg kg^{-1})	Total B in rice shoots of no B pots(mg kg^{-1})	Boron uptake by rice shoots in no B pots (µg pot $^{-1}$)
		0	0.5	1	1.5				
1.	0.62	11.6	11.4	10.9	10.0	101.7	17	24	278.4
2.	0.38	6.8	8.6	9.3	9.5	71.5	11	16	108.8
3.	0.24	6.6	9.5	10.1	11.2	59	10	14	92.4
4.	0.30	5.8	8.9	9.9	10.6	55	8.7	15	87
5.	0.40	8.5	9.1	9.2	8.8	63.0	12.5	16	136
6.	0.25	7.2	8.5	9.1	9.0	79.1	11.5	16	115.2
7.	0.24	5.4	8.7	9.8	10.6	50.9	8	11	59.4
8.	0.33	11.0	11.2	11.2	10.9	98.2	16	24	264
9.	0.18	6.1	9.2	10.0	10.7	57	10	12	195.8
10.	0.62	12.5	10.4	11.2	10.2	89.6	16	24	300
11.	0.42	10.9	11.2	10.8	9.5	97.3	16	24	254.4
12.	0.32	6.4	8.4	9.6	10.0	64	9.5	14	89.6
13.	0.38	10.2	10.6	11.0	10.8	92.7	19	26	309.4
14.	0.40	11.2	11.5	11.6	11.2	96.5	18	24	268.8
15.	0.70	14.8	13.5	12.4	10.8	109.6	24	28	414.4
16.	0.35	8.5	9.4	10.2	10.9	77.9	14	19	161.5
17.	0.43	12.6	12.6	11.4	10.2	100	18	25	315
18.	0.72	14.4	13.0	12.8	11.8	110.7	19	23	331.2
19.	0.39	10.2	12.7	12.9	11.6	79	23	26	256.2
20.	0.46	11.0	11.0	10.6	10	100	16	24	264
21.	0.36	7.9	9.1	10.5	10.7	73.8	12	18	142.2
22.	0.27	7.7	9.2	9.5	10.5	73.3	15	22	211.2
23	0.18	6.2	9.4	9.8	10.5	71.3	12	16	99.2
24	0.65	13.4	12.5	12.2	10.8	107.2	14	20	268
Mean	0.39	9.4	10.4	10.7	10.4	82.4	14.6	20	209.2
Range value	0.18-0.72	5.4-14.8	8.4-13.5	9.1-12.9	8.8-11.8	50.9-110.7	8-24	11-28	59.4-414.4

Based on the soil test, plant analysis and response of different crops to the application of B in greenhouse and field trial, the critical limit of B was 0.36 mg kg^{-1} (hot water soluble boron) and 0.50 mg kg^{-1}(hot-$CaCl_2$ extractable) for rice, wheat and oil seeds has so far been fixed for West Bengal (Das and Saha, 1999).

Boron is an important micronutrient greatly influences the yield of rice due to its nutritional value in metabolism (Berger and Troug, 1940). The data revealed that average response in dry matter yield (%) at optimum level of applied B in soils below critical limit ranged from 1.8 to 96.2 with mean value 52.5(Table 3). With increasing the level of available boron content in soil above the critical limit, the percentage responses also decreased which varied from (-) 8.8 to 56.3 per cent with a mean value of 5.7 per cent. On the other hand, the application of B significantly increased the average shoot yield from 7.2 to 10.50 g pot^{-1} upto 1.5 mg B kg^{-1} soil below the critical value (Khan *et al*., 2006). Whereas, above the critical value, the application of B fertilizer increased the average shoot yield marginally from 11.44 to 11.55 g pot^{-1} upto 0.5 mg B kg^{-1} soil. However, a substantial amount of average dry matter yield decreased with increased the level of applied boron fertilizer in the soils containing the available B above critical limit up to 1.5 mg B kg^{-1} soil. The decreased in dry matter yield at higher B levels may be ascribed to B toxicity because a slight increased in B levels markedly increased the B concentration in shoots (Rashid *et al*., 2004). Based on critical value of

Table 3. Response of rice crop to boron application

Hot water soluble B (mg kg^{-1})	No. of soils	Percentage of responding soils	Average dry matter yield (g pot^{-1})				Average response in dry matter yield (%) at optimum level of applied B	
			Level of applied B (mg kg^{-1})				range	mean
			0	0.5	1	1.5		
<0.38(Deficient)	11	90.9	7.2	9.22	9.97	10.50	1.8-96.2	52.5
>0.38(Adequate)	13	15.4	11.44	11.55	10.77	10.40	(-)10.4-39.7	3.6

A soil was classified as responsive to B where the per cent response was more than 10.

available B, soils were grouped into deficient and adequate classes (Table 3). Considering critical value of B in soils (0.38 mg kg^{-1}), 13 soils were rated to be adequate and 15.4% soils belonging to this category responding to B application. Whereas, 90.9% soils below the critical value showed the positive response to B application. However, closer examination indicated that the magnitude of mean percentage response due to 1.5 mg kg^{1} level of B application over 0 mg kg^{1} was found to be maximum (Table 2). This revealed that B can be applied safely for rice @1.5 mg kg^{1} in the soils of old alluvial zone of West Bengal, where the available B was below 0.38 mg kg^{1}. Soylu *et al* (2004) also reported that application of 1 and 3 kg B ha^{-1} in low boron content soils of Turkey increased the yield of wheat an average of 11 and 9 % respectively, while 9 kg B ha^{-1} resulted in lower overall yield 7 %.

The available B was found to be positively and significantly correlated with organic carbon (r= 0.8895**), clay (r=0.6657**), CEC (r=7756**) and Bray's percentage yield (r=0.8087**) of the soils (Table 4). Whereas, a negative relationship also observed between sand (r=-0.1581 and silt (r= -0.4169). This suggests that organic matter, clay and CEC are the major sources of available B. Similar results have also been reported by Arora and Chahal (2009) and Bhattacharyya *et al.* (2000). A positive and significant association was also found between B concentration in plant tissues of 3rd leaf and Bray's percentage yield (r =0.7763**).

Table 4. Single correlation coefficient (r-values) between available B and soil properties

Variables	r- value
Soil pH vs available B	0.0353
Organic carbon vs available B	0.8895**
Clay vs available B	0.6657**
Silt vs available B	-0.4169
Sand vs available B	-0.1581
CEC vs available B	0.7756**
Bray's percentage yield and available B	0.8087**
Bray's percent yield and B concentration in plant tissues of 3rd leaf	0.7763**

** → 1% level of significant

From the present study, it can be concluded that, the critical limit value of available B in soil and third leaf rice plants was 0.38 and 15.0 mg kg^{-1}, respectively. The application of B @ of 1.5 mg kg^{-1} soil in the study area below the available B content 0.38 mg kg^{-1} gave the significant effect on the yield of rice. This study further revealed that plant tissue test can also be used precisely for detecting hidden hunger of B deficiency in growing plants before the appearance of visible symptoms.

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