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Critical limit of available boron for rice in red and laterite soils of West Bengal

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Abstract : The critical limit of boron in soils and plant was determined in a pot culture experiment with twenty two acidic soils of red and laterite zone of West Bengal. The hot water soluble B in these soils was found to be positively and significantly correlated with organic carbon, per cent dry matter yield of rice, and its concentration in plant tissues and uptake by shoots. A negative but significant correlation was observed between pH and hot water soluble boron. The critical concentrations of available B and plant tissues-B were worked out to 0.30 mg kg^{-1} and 12.5 mg kg^{-1}, respectively. The average dry-matter yield increased with increasing level of B fertilization up to 7.5 mg kg^{-1} below the critical limit. The response to B application in rice on B deficient soils was found to be 83.2%.

Additional key words : *Bray's per cent yield, acidic soil*

Introduction

Boron is one of the 16 elements for plant growth (Joham 1986) and is involved in many plants functions. The application of B either through soil or foliar spray was found to be beneficial in stimulating plant growth and increasing yield of crops such as rice and wheat (Sakal *et al.* 2002). The yield attributes of rice (*cv.* IR-36) like plant height, panicle length, percentage of filled grains and 1000 grain weight were significantly affected by the application of B during kharif season (Mandal *et al.* 1987).

Boron has a marked effect on plant from the standpoint of both nutrition as well as toxicity (Das 2003). The range between the levels of soil B resulting in deficiency and that causing toxicity in plant is relatively small. Plant species differ characteristically in their capacity to take up B when grown in the same soil which generally reflects typical species difference in the requirement of B for growth. The apparent and latent symptoms of B deficiency have been recorded in rice and other field crops including vegetable crops being grown in acid soils of red and laterite zone. Preliminary studies based on few soil sample analysis have indicated B deficiency in soils of West Bengal (Debnath *et al.* 2009; Saha 1992). But no information was available regarding the threshold value of available B in these soils. The present investigation was, therefore, undertaken to work out the critical concentration of B in soils and rice crop which is widely grown in the region of West Bengal for making B application more rational.

Materials and Methods

Twenty two soil samples in bulk from plough layer (0-20 cm) were collected from different locations of red and laterite zone of West Bengal (Table 1). These soils belonged to order Inceptisols and Entisols.

Table 1. Soil properties and hot water soluble boron in experimental soils

District/ Sampling site	Physico-chemical properties							Hot water soluble B content (mg kg^{-1})
	pH	Organic Carbon (g kg^{-1})	Sand	Silt	Clay	Textural class	CEC Cmol(p+)kg^{-1}	
			---------- (%) ----------					
Midnapur(W)								
Bankati	6.5	4.6	22.0	44.2	33.8	sicl	14.5	0.22
Telkona	6.4	4.8	38.0	46.0	16.0	sil	7.5	0.30
Barakonda	6.2	3.0	34.0	48.0	18.0	sil	8.0	0.35
Channabila	6.1	2.9	36.0	50.0	14.0	sil	10.5	0.15
Binpur	6.0	3.3	37.0	44.0	19.0	l	11.5	0.35
Jarkonda	5.3	4.6	12.8	43.3	43.9	sic	16.1	0.40
Anandapur	6.4	5.2	54.5	26.6	18.9	sl	7.7	0.30
Bankura								
Jharia	5.9	4.6	49.5	31.0	19.5	l	10.8	0.20
Deuli	5.8	2.8	53.4	25.0	21.6	scl	10.7	0.40
Mirgindihi	4.5	3.2	63.4	26.0	10.6	sl	7.1	0.30
Bhulanpur	5.0	2.8	48.4	30.0	21.6	scl	12.5	0.35
Dayalpur	5.6	4.0	46.5	30.0	23.5	l	11.2	0.45
Kontaban	5.9	3.1	44.4	35.0	20.6	l	9.7	0.40
Ranga	4.7	2.8	59.2	30.0	10.8	sl	6.2	0.30
Taldangra	4.8	4.4	60.0	20.0	20.0	sl	7.4	0.25
Purulia								
Sirkabad	5.9	4.9	45.6	34.9	19.5	l	8.0	0.30
Bahal	5.1	3.4	50.6	37.1	12.3	l	6.3	0.20
Pataphari	5.5	6.1	63.0	20.0	17.0	sl	7.0	0.32
Birbhum								
Chimpai	6.0	4.8	47.1	25.9	27.0	scl	13.5	0.36
Jagadishpur	4.8	4.8	30.2	55.0	14.8	sil	10.5	0.30
Kharbona	5.5	5.9	66.0	18.8	15.2	sl	7.9	0.15
Nanoor	5.6	2.8	14.2	60.8	25.0	sil	11.7	0.35
Mean								0.30

sicl=silty clay loam, sil=silt loam, l=loam, sic=silty clay, sl=sandy loam, scl=sandy clay loam

The air dry soil samples passed through 2mm sieve were analyzed for mechanical analysis by hydrometer method (Day 1965), pH by glass electrode pH meter (1:2 soil:water), organic carbon by Walkley and Black's wet digestion method (Jackson 1973) and cation exchange capacity was determined by leaching the soil with 1 *N* NH_4^+OAC and subsequently displacing the adsorbed NH_4^+ following the methods of Schollenberger and Simon (1945). Hot water soluble B was determined colorimetrically using Azomethine – H-method of Wolf (1971). Co-efficient of correlation (r) value was calculated by following the procedures as described by Gomez and Gomez (1984).

A pot culture experiment was conduced in a green house at the Instructional farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur,West Bengal,India. Each pot was lined with polythene sheet. The polythene lining was rinsed in 0.1*N* HCl 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 through urea, KH_2PO_4 and KCl. Three 21 days old rice seedling (variety IR 36) were transplanted in each pot. Boron was applied @ 0, 2.5, 5 and 7.5 mg kg^{-1} 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 other agro-managements were applied as and when required. Above ground portion of rice plant was 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 powdered plant samples were ashed in a muffle furnace at 600 °C 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 B in soil and plant has been determined by plotting percentage yield against soil available B and plant tissue B concentration respectively using the procedure of Cate and Nelson (1965). The percentage yield was calculated as:

$$\text{Bray's percent yield} = \frac{\textit{Yield without boron treatment}}{\textit{Yield at optimum boron treatment}} \times 100$$

Results and Discussion

Physico-chemical Properties of soils

The soil texture ranged from sandy loam to silty clay loam, pH from 4.5 to 6.5, organic carbon from 2.8 to 6.1 g kg^{-1} and cation exchange capacity from 7.0 to 16.10 cmol(p^+)kg^{-1} (Table 1). The soils are mostly acidic in reaction. More than 85 per cent soils were low in organic carbon, having values less than 5.0 g kg^{-1} (Debnath *et al.* 2009).

Critical limit value of B in soils and third leaf of rice plant

The available B in these soils varied from 0.15-0.45 mg kg^{-1} with mean value 0.30 mg kg^{-1} (Table 1) and percentage to dry-matter yield of rice ranged from 47.5-105% (Table 2). The boron concentration in 3rd leaf of rice, total B in entire shoot and B uptake in rice shoot in control pots ranged from 7-21 mg kg^{-1}, 9-23 mg kg^{-1} and 34.2 - 285 μg/pot, respectively (Table 2). The plot of percentage yield against soil available B and plant tissue B indicated 0.30 and 12.5 mg kg^{-1} respectively, as the critical concentration of B in soils and rice plant (Fig. 1 and 2). This critical limit of available B is very close to 0.36 mg kg^{-1} (Giri 1999). Out of the 22 soils samples, 16 soils had available B above the critical limit (0.30 mg kg^{-1}), whereas, 6 soils were in the category of below critical limit (Table 3).

Effect of B on dry matter yield

The percentage response on shoot yield of rice due to B application in soils below critical limit ranged from 18.7 to 52.6 % (mean 36.3 %) at 2.5 mg kg^{-1} level, 42.2.0 to 81.5 % (mean 62.6 %) and 56.2 to 110% (mean 83.2%) at 5 and 7.5 mg kg^{-1} of B application, respectively. On the other hand, soils above the critical level of B where dry-matter yield response at 2.5 mg kg^{-1} of applied B ranged from (-) 4.8 to 29.3 % (mean 9.5 %) and at 5 and 7.5 mg kg^{-1} level of applied B ranged from - 6.4 to 42.6 % (mean 13.5 %) and -7.5 to 51.4 % (mean 13.8 %), respectively (Table 3). On the basis of this critical limit of 0.30 mg kg^{-1}, it may be inferred that all the soils testing below this critical value markedly responded to B fertilizer application, whereas, a negative response to B application above the corresponding critical level also recorded in these soils (Table 3). Soils containing available B above the critical limit have the capacity to supply the sufficient amount of available B to crop. Hence, it is possible to get less response or negative response of crop to B application. Rashid *et al.* (2004) reported that application of B (1 $kgha^{-1}$) substantially increased grain yield of rice cultivars Basmati 385 and Super Basmati in Punjab. They also showed that plant

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

Soil No.	Shoot weight (g pot $^{-1}$) Application of B (mg kg^{-1}) 0	2.5	5	7.5	Percent dry matter 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 $^{-1}$)
1.	6.4	7.6	9.1	10.0	64.0	9	12	76.8
2.	7.9	9.5	10.7	11.3	69.9	10	14	110
3.	9.1	10.0	9.8	9.5	91.0	12	18	163
4.	4.3	6.1	7.4	8.3	51.8	7	10	43
5.	9.4	10.0	9.8	9.7	94.0	14	20	188
6.	11.9	11.8	11.5	11.0	100.0	19	23	273
7.	6.8	7.9	9.7	10.3	66.0	8	14	95.2
8.	4.4	6.4	7.6	8.5	51.7	9	12	52.8
9.	11.4	11.0	10.8	10.7	103.0	20	22	250
10.	7.2	8.8	9.6	10.3	69.3	10	13	93.6
11.	11.9	12.1	11.6	11.3	98.3	18	23	273
12.	12.4	11.8	11.6	11.5	105.0	20	23	285
13.	11.0	10.7	10.5	10.3	102.0	21	23	253
14.	7.5	9.7	10.5	11.1	67.6	11	13	97.5
15.	5.2	6.4	7.7	8.8	59.0	9	11	57.2
16.	8.4	10.5	11.9	11.0	71.6	12	16	134
17.	4.9	6.7	7.8	8.7	56.3	8	10	49
18.	8.9	9.5	9.4	9.3	93.6	15	21	186
19.	9.7	10.1	9.8	9.7	96.0	16	22	213
20.	8.2	9.6	10.2	10.0	80.3	11	17	139
21.	3.8	5.8	6.9	8.0	47.5	7	9	34.2
22.	9.5	10.0	9.8	9.75	95.0	15	22	209

height, number of productive tillers of both cultivars increased with B application. Soylu *et al.* (2004) also reported that application of 1 and 3 kg B ha^{-1} in low boron content soils (0-19 ppm) with high $CaCO_3$ content (20.72%) 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 increase by only 7 %.

Relationship between Available B, B concentration in plant tissues with dry matter yield and Soil physico-chemical properties

The available B was found to be positively and significantly correlated with organic carbon (r =0.817**) and clay (r = 0.790 **) of the soils. This suggests that organic mater is one of the major sources of available B. Whereas, a negative but significant relationship was also observed between pH (r = -0.815**) and hot water soluble (HWS) boron. Similar results have also been reported by Bansal *et al.* (2003) and Yashoda *et al.* (2003). The available B was observed (Table 4) to be positively and significantly correlated with Bray's percentage yield (r = 0.933**) and a similar association was also observed between B concentration in plant tissues of 3rd leaf and Bray's percentage yield (r = 0.935**). A highly significant positive correlation between available B and Bray's percentage yield denotes that hot water is a promising extractant for demarcating B deficient from non-deficient soil. From the analysis of Brown forest and

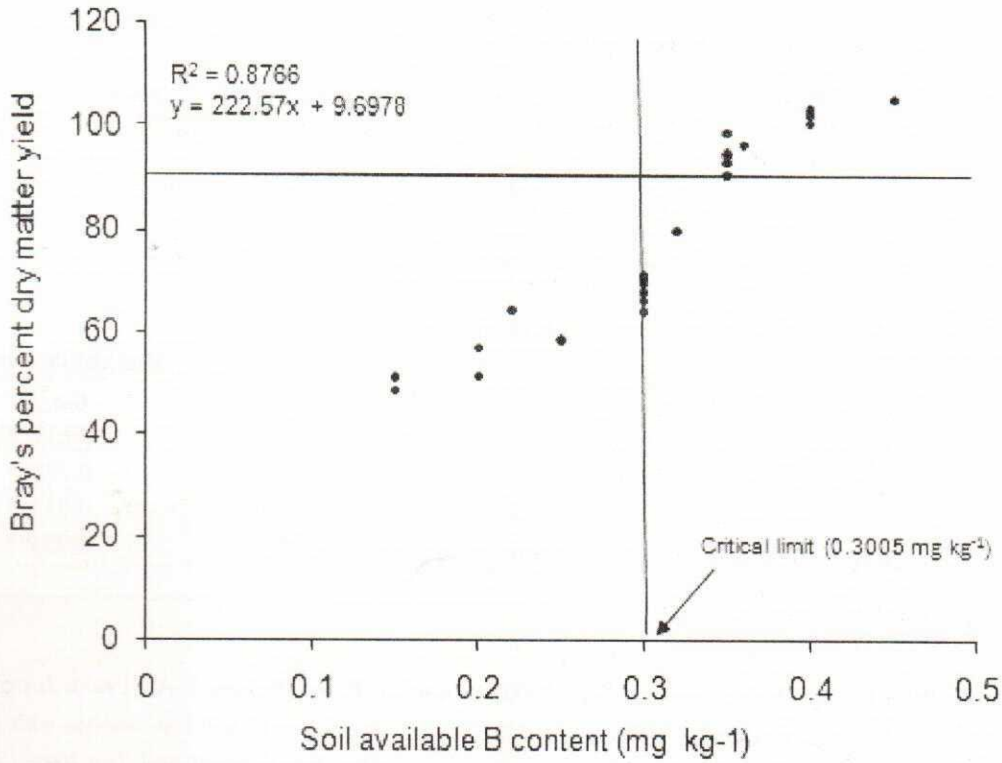

Fig. 1. Scatter diagram of hot water soluble B vs per cent dry-matter yield of rice grown in soils of red and laterite zone of West Bengal

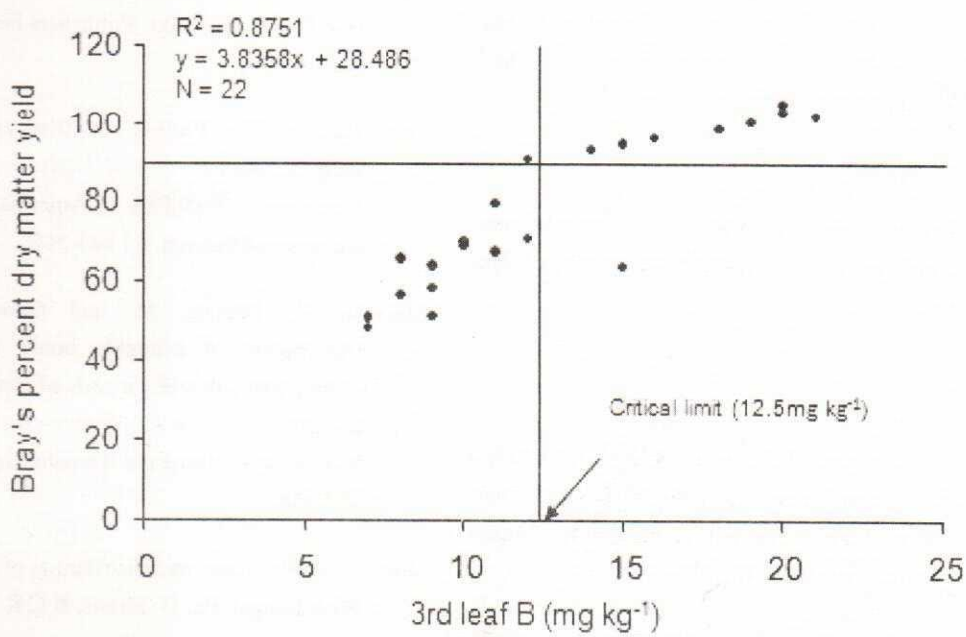

Fig. 2. Scatter diagram of third leaf B vs per cent dry matter yield of rice grown in soils of red and laterite zone of West Bengal.

Table 3. Response of rice crop to boron application

Hot water soluble B ($mg\ kg^{-1}$)	No. of soil	Average response in yield (%) at optimum level of applied B		Percentage yield response at					
				2.5 ($mg\ kg^{-1}$)		5 ($mg\ kg^{-1}$)		7.5 ($mg\ kg^{-1}$)	
		range	mean	range	mean	range	mean	range	mean
<0.30	6	56.2-110.5	83.3	18.7- 52.6	36.3	42.2-81.5	62.6	56.2-110	83.2
>0.30	16	(-)4.8-51.5	17.1	(-)4.8-29.3	9.5	(-)6.4- 42.6	13.5	(-)7.5-51.4	13.8

Table 4. Correlation coefficients (r-values) between variables

Sl. no.	Variables	Red and laterite zone
1	Soil pH vs available B	- 0.815**
2	Organic carbon vs available B	0.817**
3	Clay vs available B	0.790**
4	Bray's percentage yield and available B	0.933**
5	Bray's percent yield and B concentration in plant tissues of 3rd leaf	0.935**

*** 1% level of significant*

Tarai soils of West Bengal, Bhattacharyya *et al.* (2000) observed that total B was significantly and positively correlated with CEC ($r = 0.89^{**}$) of the soils.

The present study, thus indicates that, the critical limit value of available B in soil and third leaf rice plants was 0.30 and 12.5 $mg\ kg^{-1}$, respectively. The application of B @ 7.5 $mg\ kg^{-1}$ in the study area, below the available B content 0.30 $mg\ kg^{-1}$ significantly influenced the yield of rice.

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