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Critical Limit of Boron in Soil and Plant

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Abstract A pot culture experiment was conducted on maize to study critical limit of boron (B) in seven different types of acid soils of Odisha. The hot water soluble (HWS) boron in these soils was positively and significantly correlated with pH, CEC, clay and percent dry matter yield of maize, B concentration at plant tissues and B uptake by shoots. The critical concentration of soils available B and plant tissue B was 0.54 mg kg^{-1} and 19 mg hg^{-1} respectively, below which appreciable responses to B application were observed. The response of maize to B application in B deficient soils was 33.5%.

Keywords Boron, Bray's percent yield, Critical limit, Acid soil, Maize.

Introduction

With increasing cropping intensity and high yielding crop varieties grown with increasing use of secondary and micronutrients free fertilizers, the exhaustion of native soil sources of secondary and micronutrients have increased considerably. Boron is an essential micronutrient required for crop growth. It acts as new cell developer in meristematic tissue, fruit and seed setting is involved in the regulation of the carbohydrate metabolism and its transport within the plant.

Boron has marked effect on plant from the stand point of both nutrition as well as toxicity (Das 2003). Soil boron resulting in deficiency and that causing toxicity in plant, is relatively small. The critical limit of B in plant below which plant either develops deficiency symptoms or causes significant 5-10% reduction in yield as compared to optimum. Plant species of different character have a capacity to take up B when grown in same soil which generally reflects typical species difference in the requirement of B for growth. Pal and Jena (2012) reported that B deficiency in the soils of 92 blocks covering 12 district of Odisha ranged from 8-63% with a mean of 42%. Pal et al. (2015) reported that HWS-B in maize growing soils of Nabarangpur district of Odisha were in the range of 0.035 to 20.53 ppm with a mean of 0.049 ppm and deficiency were 13 to 65%. But no information is available regarding the threshold value of available B in these soils. Hence the present study was conducted to workout the critical concentration of B in soil and maize crop for making boron application more rational .

Materials and Methods

Seven soil samples comprising of seven soil groups in bulk from plough layer (0-15 cm) were collected from different locations of Odisha. These soils belonged to seven soils groups i.e. Black soil, mixed red

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Table 1. Physico-chemical properties of soils used for B adsorption studies.

Sl. No.	Soil type	pH	EC (dS m^{-1})	OC (g kg^{-1})	HWB (mg kg^{-1} soil)	CEC [cmol (p+) kg^{-1}]	Soil separates (%) Sand	Silt	Clay	Texture	$CaCO_3$ (%)
1	Red soil	4.64	0.1	3.3	0.36	3.5	78.8	10.9	10.3	Sandy loam	5
2	Black soil	6.26	0.23	9.8	0.68	36.7	22.4	42	35.4	Silty clay loam	6.6
3	Brown forest soil	5.29	0.06	13.3	0.48	8.3	82.8	4.9	12.3	Sandy loam	0.4
4	Alluvial soil	4.98	0.06	1.1	0.53	4.9	79.7	4.9	15.4	Sandy loam	3.5
5	Laterite soil	4.5	0.06	1.3	0.32	1.94	84.8	4.9	10.3	Sandy loam	0.4
6	Red and yellow soil	6.89	0.28	5.5	0.52	8.3	75.7	8	16.3	Sandy clay loam	3
7	Red and black soil	6.3	0.13	2.6	0.56	8.5	73.7	6.9	19.4	Sandy loam	5.2

and black soil, brown forest soil, alluvial soil, red soil, laterite soil and mixed red and yellow soil. According to the soil groups, Black soil, mixed red and black soil and brown forest soil may be classified under *Vertisols,* Alluvial soils under *Inceptisols* and Red soil, laterite soil and mixed red and yellow soil under *Alfisols*.

The air dried soil samples were passed through 2 mm sieve. The properties like pH and electrical conductivity (EC) were done on 1:2 Soil: Water (W/V) suspension using pH meter and EC meter following half an hour equilibration (Jackson 1973). The mechanical analysis was done by bouyoucos hydrometer (Black 1965) and organic carbon was estimated by Walkley and Black wet digestion method (Walkley and Black 1934). The cation exchange capacity (CEC) of soil was determined by leaching the soil with 1N NH_4 OAc and subsequently displacing the adsorbed NH_4^+ following the method of Schollenberger and Simon (1945). Hot water soluble boron was estimated with UV-visible spectrophotometer using Azomethine-H, method of John et al. (1975). A pot culture experiment was conducted taking five kg soil in each pot with recommended dose of N-P_2O_5-K_2O @ 80-40-40 kg ha^{-1}. Boron was applied @ 0, 1.2, and 4 kg ha^{-1} as soil application and then maize *(Zea mays)* var. Madhury seed were sown in each pot. Each treatment is replicated 4 times. After 60 days maize plant were harvested above ground portion and washed in acidified solution, rinsed with deionized water, dried at 65^0 C in a hot air oven and dry matter was recorded. The dried maize plant and dried 3rd leaf samples of each treatment were separately powdered. The dry powdered plant samples were kept for analysis.The concentration of B was determined colorimatrically using Azomethine-H method (John et al. 1975). The critical concentration of boron in soils and plants were determined by plotting percentage yield against soil available B and plant tissue B concentration, respectively, following graphical procedure of Cate and Nelson (1965). Bray's percent yield of maize was calculated as follows.

Table 2. Effect of boron application on dry matter yield, boron concentration in leaf and shoot and boron uptake by maize.

Sl. No.	Shoot weight (g/pot) Application of B (mg kg^{-1} soil) 0	1	2	4	Bray's % yield at optimum B level	Total B in the 3rd leaf of no-B pots (mg kg^{-1})	Total B in shoots of no-B pots (mg kg^{-1})	B uptake by shoots in no-B pots (µg kg^{-1})
1	65.5	73.7	75.7	72	86.5	10	11	720.5
2	52.5	61.3	69.5	62.3	75.5	12	14	735
3	45	49.1	58.1	51.2	77.5	22	24	1080
4	42.5	49.4	54.2	43.5	78.4	20	22	935
5	35	40	45.7	37.5	76.5	20	23	805
6	35.7	40.5	42.9	41.8	83.2	19	22	785.4
7	33.3	41.2	49.3	40.6	67.5	18	20	666
Mean	44.21	50.74	56.48	49.84				

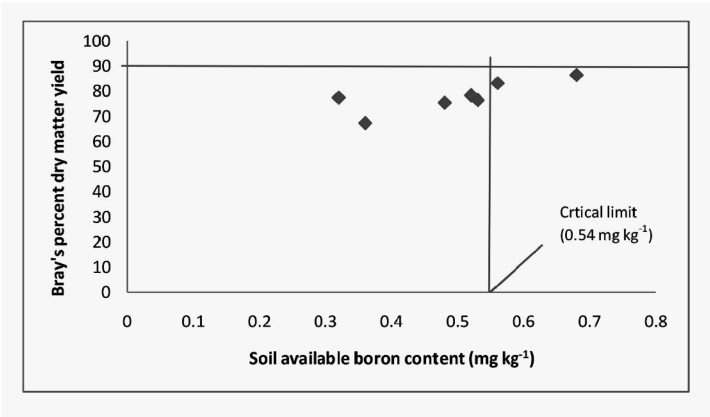

Fig. 1. Scatter diagram of hot water soluble boron of soil v/s percent dry matter yield of maize.

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

Further, the data obtained from graphical procedure was again computed as per statistical model described by Cate and Nelson (1971) by using corrected sum of square for the population, predictability value (R^2) and postulated critical value. Simple correction analysis was carried out to establish the relationship between the available B and soil properties.

Results and Discussion

Physico-chemical properties of soils

The soil texture varied from sandy loam to silty clay loam. pH ranged from 4.5 to 6.89, organic carbon content from 1.1 to 13.3 g kg^{-1} and cation exchange capacity from 1.94 to 36.70 cmol (p^+) kg^{-1} (Table 1). Most of the soil have lower organic carbon.

Critical limit of B and third leaf maize plant

The available B in these soils varied from 0.32 to 0.68 mg kg^{-1} with a mean value of 0.49 mg kg^{-1}(Table 1). The percentage dry matter yield of maize range from 67.5 to 86.5 with a mean value of 77.87. The B concentration of third leaf of maize plant, total B in entire shoot and B uptake by maize shoot in no B applied pots ranged from 10-22 mg kg^{-1}, 11-24 mg kg^{-1} and 666-1080 µg pot^{-1} respectively. The dry matter yield of maize increased upto B application @ 2 mg kg^{-1} and

Table 3. Statistical estimation of critical limit of boron in acid soil of Odisha. CCSS: Corrected sum of square of deviation from mean of population.

Sl. No.	Soil Av B (mg kg^{-1})	BPY %	(BYP)^2	CSS	R^2	Class I	Class II	GT^2/7	CCSS
1	0.68	86.5	7482.25						
2	0.48	75.5	5700.25	27.40629	0.001088	13122	29353.122	42447.71571	25187.5788
3	0.32	77.5	6006.25	4209.888	0.167141	19120.0833	23347.84	38258.03571	23067.3012
4	0.52	78.4	6146.56	4213.68	0.167292	25265.1025	17206.613	38258.03571	23067.3012
5	0.53	76.5	5852.25	4207.481	0.167046	31110.272	11355.245	38258.03571	23067.3012
6	0.56	83.2	6922.24	4315.174	0.171322	38016.96	4556.25	38258.03571	23067.3012
7	0.36	67.5	4556.25	0	0				
Sum	3.45	545.1	42666.05						
Sum sq	11.9025	297134							

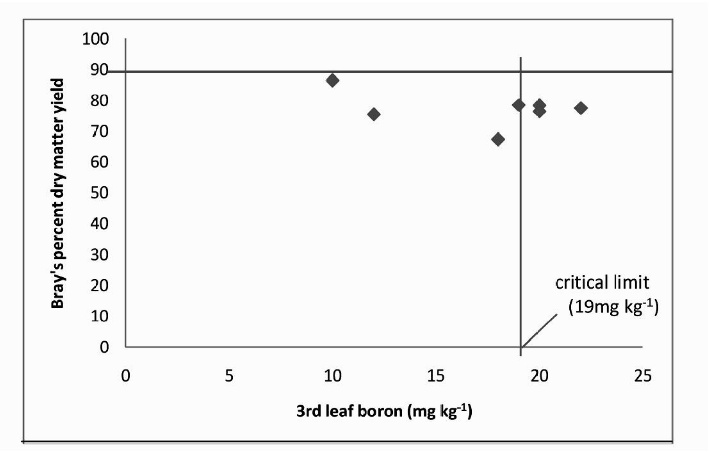

Fig. 2. Scatter diagram of third leaf boron v/s percent dry matter yield of maize.

then decreased (Table 2). The data in the Table 2 were subjected to established critical soil boron by adopting the procedure described by Cate and Nelson (1965). In graphical presentation, boron soil test values were plotted on X-axis and Bray's percent yield values on Y-axis (Fig. 1). Accordingly the critical limit of hot water boron in soil and plant tissue B was found to be 0.54 mg kg^{-1} and 19 mg kg^{-1} respectively (Figs. 1 and 2).

Further, data on available soil boron corresponding to correct sum of squares for population, postulated critical value and predictability value (R^2) were computed as per statistical model described by Cate and Nelson (1971) and presented in Table 3. The R^2 values ranged between 0.001 to 0.171. The corresponding boron concentration against highest R^2 values was 0.56 mg kg^{-1} which is the calculated critical limit of soil available boron. Accordingly critical limit for plant tissue was found to be 19 mg kg^{-1} (Fig. 2). However, critical limit of soil available B and plant tissue B of 0.35 and 12 mg kg^{-1} in rice plant were earlier reported by Debnath and Ghosh (2012).

Critical available boron values obtained from graphical (0.54 mg kg^{-1}) and statistical (0.56 mg kg^{-1}) approaches showed no difference and both methods appeared to be equally precise in predicting the deficiency of boron in maize growing areas. Similar critical values was reported by Sakal et al. (1987) on black gram, Maleswar et al. (1999) on cauliflower.

Effect of boron in dry matter yield

Average response in percent dry matter yield at optimum level of applied B in soils below critical limit ranged from 27.5 to 48 with a mean of 33.5 and above critical limit, the percentage responses varied from

Table 4. Response of maize crop to boron application.

Sl. No.	HWS-B (mg kg^{-1})	No. of soils	Average dry matter yield (g pot^{-1}) Level of applied B (mg kg^{-1})				Average response in dry matter yield (%) at optimum level of applied B	
			0	1	2	4	Range	Mean
1	< 0.54	5	41.66	48.2	55.36	47.02	27.5-48	33.5
2	> 0.54	2	50.6	57.1	59.3	56.9	15-20	17.5

Table 5. Simple correlation coefficients (r) between available B and soil properties. *Significant at 5% level.

Sl. No.	Variable	r
1	Soil pH vrs available B	0.79*
2	CEC vrs available B	0.78*
3	Clay vrs available B	0.86*
4	Bray's percentage vrs available B	0.77*

15-20 with a mean of 17.5 (Table 4). On the other hand application of B significantly increased the average shoot yield from 44.2 to 56.5 g pot^{-1} upto 2 mg B kg^{-1} soil, thereafter decrease in yield occurred. The decreased in dry matter yield at higher B levels may be ascribed to B toxicity because a slight increase in B levels markedly increased concentration in shoot (Rashid et al. 2004, Sakal et al. 1993).

Boron in soils and plant in relation to soil physico-chemical properties

The available B was found to be positively and significantly correlated with pH (r=0.79*), CEC (r=0.78*) and clay (r=0.86*). Similar results have also bean reported by Datta et al. (1988), Bhatacharyya et al. (2000) and Debnath and Ghosh (2012). The available boron was observed to be positively and significantly correlated with Bray's percent yield (r = 0.77*) (Table 5).

Conclusion

It is inferred in the present study, that the critical limit of available B in soil and third leaf of maize plant were 0.54 and 19 mg kg^{-1} respectively. Optimum yield of maize was responded significantly upto B applied @ 2 mg kg^{-1}.

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