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Short Research Article

Determination of Critical Limit of Boron for Rice, Groundnut and Potato Crops in Red and Laterite Soils of Odisha

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Abstract

A study was conducted to assess the critical limit of boron (B) for groundnut, rice and potato in red and laterite soil (n=10) of Mayurbhanj district of Odisha. The availability of B content in the experimental soil ranged from 0.34 to 0.85 with mean value of 0.59 mg kg^{-1}. The pH, texture, organic carbon, CEC and boron content of soil along with boron level in the third leaf and biomass yield of crops were determined after applying the recommended dose of NPK. The ten different red and laterite soils used were found to be acidic in reaction (pH 4.72−5.84), loamy sand to silt loamy texture and low to medium organic carbon content. About 30% boron deficiency was there in the examined soil samples. The critical level of B in red and laterite soils was 0.56, 0.52 and 0.56 mg kg^{-1} in soils for rice, groundnut and potato crop whereas for the corresponding leaves it was 23, 19 and 26 mg kg^{-1}, respectively. The Bray's percent dry matter yield of rice, groundnut and potato in B treated soils were varied from 52.3−118, 40.5−99 and 62−92, respectively. The maximum biomass yield was recorded in rice and groundnut at 1.5 kg B ha^{-1} and potato at 2.0 kg B ha^{-1} level indicating knowledge of critical concentration will help in maximizing the yield and performance of crop.

1. Introduction

Red and laterite soils are predominant occupying more than 45% of total land area in Odisha. In general, most of these soils are poor in major nutrients (organic matter, N, P, Ca, Mg, S) except K. The same is also true for micronutrients like Zn, B and Mo. Thus, deficiency of macronutrients and micronutrients in crops are very commonly observed in red and laterite soils (Jena et al., 2008). A steep rise in population has forced for intensive cropping and use of high yielding crops without proper dose of fertilizers, which resulted in further depletion of micronutrients from soil reserve (Sakal et al., 1996; Singh, 2008; Powlson et al., 2011). These factors further result in a sharp reduction in productivity, crop quality as well as animal and human health.

Among micronutrients boron (B) nutrition got a special importance because of the wide spread deficiency of B in crops (Singh et al., 2006; Singh, 2012; Prasad et al., 2014). They further observed that, out of 33, 000 soil samples 45% samples were found to be deficient in B (0.5 mg kg^{-1} hot water soluble B as the critical level). Boron deficiency is further affected by coarse texture, low pH, low organic carbon, and leaching under high rainfall (Singh, 2008; Jones et al., 2013; Dey et al., 2015; Wimmer et al., 2015).

Available nutrient status of soils is a potent indicator for crop response to the nutrients (Ali et al., 2013). Therefore, soil test values are considered for recommending fertilizer with slight variations. Based on several field and green house experiments, Singh et al. (2006) reported the critical value of B as 0.5 mg kg^{-1}. Crops grown on soils with available nutrient status below the critical limit are likely to be deficient and sensitive crops would show deficiency symptoms and respond well to addition of that deficient nutrient (Powlson et al., 2011; Wimmer et al., 2015). Potato crop responds to application of B. But, the critical limit of B presently followed for different soils is a generalized one and no specific limit is available for red and laterite soils. Critical limit of a soil and/or crop is specific and knowledge of the critical limit helps in determining the exact amount of fertilizer needed for the specific crop and micro agroclimatic situation prevalent at the farm. Keeping the above points into consideration, the present pot culture study was undertaken to determine the critical concentration of B in soils along with rice, groundnut and potato crop to make micro and secondary fertilization more effective and rational.

2. Materials and Methods

Ten soil samples in bulk from plough layer (0−15 cm) covering red and laterite soils were collected from five blocks of Mayurbhanja district of Odisha in 2012−13. Rice is the main crop of the district in *kharif* followed by groundnut in *rabi* grown under residual moisture condition, whereas potato is grown in irrigated command areas. The collected soil samples were air dried, processed and kept in air tight containers for analysis. Particle size was measured by Bouyoucos hydrometer method (Bouyoucos, 1962), soil pH by glass electrode with calomel as standard (Jackson, 1973) and cation exchange capacity (CEC) by method suggested by Schollenberger and Simon (1945). Organic carbon (OC) was determined by wet digestion method of Walkley and Black (1934), whereas the hot water soluble B was determined by Azomethine-H method (Page et al., 1982).

Three pot culture experiments were conducted in a completely randomized design (CRD) with three replications each in *kharif* 2012 (rice) and during *rabi* 2012−13 (groundnut and potato). The pot culture experiments were conducted with ten soils (Table 1) in polyethylene lined earthen pots. The polyethylene lining was rinsed with 0.1 N HCl followed by deionised water. Seven kg of soil was transferred into each pot. The treatments consist of seven levels of B (0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 kg ha^{-1}). All these treatments were imposed on rice, groundnut and potato. In rice experiment, three rice seedlings (cv. Pratiksha) of twenty five days old were transplanted with recommended dose of fertilizer (N, P, K @ 80-40-40 kg ha^{-1}). In groundnut and potato experiments, four seeds of groundnut (cv. AK 12-24) and potato (cv. Kurfijyoti) seeds were sown with recommended dose of fertilizer @ 20-40-40 and 120-60-90 kg NPK ha^{-1}, respectively. The crops received reagent grade of fertilizer through urea, single super phosphate and murate of potash. Required quantity of borax was thoroughly mixed with soil before transplanting. Watering with deionised water and plant protection measures were taken as and when necessary. The rice plants were harvested at pre-flowering stage, whereas groundnut and potato were harvested at maturity. The plant, pod and tuber samples were washed with acidified solution, rinsed with deionised water, dried at 65 °C in a hot air oven and dry matter yield (DMY) were recorded. The third leaf samples collected at 30 days of growth were processed and kept for analysis. The dry powered plant samples were digested in a mixture of 10:4:1 of HNO_3; $HClO_4$; H_2SO_4 on a hot plate and filtered through Whatman No. 42 filter paper for estimation of B. The critical limit for B of soil and crops were determined by plotting the Bray's percent yield against soil available B or its concentration in plants following method of Cate and Nelson (1965). Simple correlation was carried out to establish the relationships between nutrient and soil properties.

Bray's per cent yield = (yield in control/yield at optimum nutrient treatment)×100

3. Results and Discussion

3.1. Physical and chemical properties of soils

The results revealed that the soils were acidic in reaction (pH, 4.72 to 5.84; Table 1). Except Agria, the pH of other nine sites

Table 1: Physico-chemical properties of soils used in pot culture study

Sl. No.	Locations	pH	Organic carbon (%)	Sand (%)	Silt (%)	Clay (%)	Textural class	CEC [Cmol (p+) kg^{-1}]	Available (mg kg^{-1})		
									Zn	B	S
1.	Balidhia	4.87	0.50	72	19	9	LS	38	0.45	0.35	5.0
2.	Paikabasa	4.76	0.53	66	24	10	L	4.2	0.90	0.72	8.0
3.	Patisari	4.87	0.66	63	25	12	Ll	4.5	0.58	0.80	10.0
4.	Jadunathpur	4.86	0.35	72	20	8	LS	3.7	1.50	0.42	7.5
5.	Kaliana	4.72	0.44	67	24	9	LS	4.0	1.60	0.85	6.0
6.	Marangtandi	4.95	0.48	63	26	11	SiL	5.8	0.75	0.55	15.0
7.	Betna	4.80	0.43	70	21	9	LS	3.8	0.35	0.34	3.0
8.	Rajabasa	4.94	0.68	58	28	14	SiL	5.7	0.52	0.81	16.0
9.	Santhilo	4.97	0.68	55	31	14	SiL	5.6	0.38	0.53	12.5
10.	Agria	5.84	0.48	67	23	10	LS	6.0	0.65	0.57	14.0
Range		4.72−5.84	0.35−0.68	55−72	19−31	9−14		3.7−6.0	0.35−1.60	0.34−0.85	5.0−16.0
Mean		4.95	0.52	65.3	24.1	10.6		4.71	0.76	0.59	9.7
SD		0.32	0.11					0.94	0.44	0.19	4.50

was below 5.0. The soil texture varied from loamy sand to silt loam. Soil acidity and coarse soil texture lead to leaching of B, thereby causing their deficiency in soils and plants. Higher clay content (14%) was recorded in two soils (Rajabasa and Sathlo) and in other sites, it varied between 8–12%.

Similar trend was observed in silt content (19–31%). A reverse trend was recorded with respect to sand content (55–72%), the highest being in Balidhia and the lowest in Sathilo. The organic carbon (OC) status of soils revealed that out of ten sites, five had low OC content and others had medium values. The results further revealed that about 30% soils are deficient in B. Organic carbon content of soils was closely correlated with clay content with high correlation co-efficient (R=0.87*).

3.2. Critical limit of nutrient

The relationship between soil test level and relative yield vary considerably, but the shape of the relationship is relatively consistent. At low level of available nutrient, the yield is limited by lack of the nutrient. As the soil test level increases, the yield increases until a point, where the nutrient is no longer limiting the yield and thus the curve levels out. Above this level the yield may decline. The point where the curve levels off is called critical level. Effect of different treatments on biomass yield (g pot^{-1}) and B concentration in rice, groundnut and potato leaves are presented in Tables 2–4. The scattered diagram of dry matter yield (%) of rice, groundnut and potato and available B in soil and the third leaves of respective plants are mentioned in Figure 1-6. The plot of Brays % yield against soil available B revealed 0.56, 0.52 and 0.56 mg kg^{-1} as the critical concentration of B in soils for rice, groundnut and potato crop, whereas the respective values for plants were 23, 19 and 26 mg kg^{-1}.

However, in an experiment on black gram, Sakal et al. (1996) reported the critical limit of hot water B and plant tissue B in alluvial soils of Bihar to be 0.52 and 23.5 mg kg^{-1}, below which appreciable responses to B application was observed. Based on the soil test, plant analysis and response of different crops to B application in green house experiment and field trials, the critical limit of B was 0.36 mg kg^{-1} (hot water soluble B) and 0.5 mg kg^{-1} (hot $CaCl_2$ extractable B) for rice, pulses and oilseeds for acidic soils of West Bengal (Das and Saha, 1999). Rattan et al. (2009) reported the critical limit of hot water extractable B for rice, maize, soybean, black gram and cauliflower across the soil types as 0.48 mg kg^{-1}. This shows that the critical limit of hot water extractable B have been revolving around 0.5 mg kg^{-1}. However, in present study the critical limit for rice and potato was higher (0.56 mg kg^{-1}) than groundnut (0.52 mg kg^{-1}) indicating that groundnut requires more B than rice and potato. About 0.52 mg kg^{-1} of hot water soluble B is sufficient for rice and potato, whereas groundnut would suffer. However, the average value of 0.54 mg kg^{-1} is considered as the critical limit of hot water soluble B for rice, groundnut and potato for acidic Alfisols. In a recent study, based on the results of a pot culture experiment, Mahendran et al., (2016) reported the critical limit of B to be 42.7 mg kg^{-1} for groundnut plants and 0.39 mg kg^{-1} in Madurai soils. The value in our present experiment for groundnut crop is higher, which might be attributed to the differences in soil types.

Table 2: Effect of different treatments on biomass yield (g pot^{-1}) and B concentration in rice leaf

Soil	Av. B	Biomass yield (g pot^{-1})							Bray's P yield (%)	B content in 3rd leaf in B control (mg kg^{-1})
		Levels of boron (kg ha^{-1})								
		0	0.5	1.0	1.5	2.0	2.5	3.0		
1	0.35	92.4	110.6	140.5	176.7	160.5	105.0	99.0	52.3	12
2	0.72	95.0	82.6	80.6	80.0	75.0	73.0	73.0	115.0	25
3	0.80	96.0	81.4	81.9	80.0	75.0	73.0	74.0	118.0	29
4	0.42	90.0	105.6	122.0	138.6	118.0	110.0	110.0	65.0	18
5	0.85	100.0	88.5	88.0	80.0	75.0	76.0	70.0	113.0	24
6	0.55	94.0	128.0	134.3	129.5	122.0	105.0	98.0	70.0	16
7	0.34	90.0	125.0	138.0	140.6	132.0	130.0	105.5	64.0	15
8	0.81	102.0	118.0	130.8	122.0	105.0	90.0	88.0	78.0	22
9	0.53	92.0	125.0	131.4	130.5	125.0	104.5	100.8	70.0	20
10	0.57	105.0	115.6	119.3	118.0	112.0	100.0	88.0	88.0	23
Range	0.34–0.85	90.0–105.0	81.4–128.0	80.6–140.5	80.0–176.7	75.0–160.5	73.0–130.0	73.0–110.0	52.3–118.0	12–29
Mean	0.59	95.64	108.03	116.68	119.59	109.95	96.65	90.63	83.33	20.4
SD		5.13	17.89	23.84	31.60	28.22	18.53	14.34		5.18

3.3. Crop response to boron

The soils used for pot culture study falls under three categories- low (30%), medium (40%) and high (50%). Variations in available B content of soils influence biomass yield of crops differently at various levels of B application. In general the biomass yield of rice, groundnut and potato in B control treatment was lower in B deficient soils and increased in medium and high B content soils. With application of different doses of B, in deficient soils, there was sharp increase in yield of rice and groundnut, attained its peak at 1.5 kg ha^{-1} dose and there after decreased at 2-3 kg B ha^{-1} dose. But in case of medium to high B content soils, the peak rice yield is achieved at lower dose of B application (1.0 kg ha^{-1}) and decreased with increasing level of B might be due to toxic effect. However, the

Table 3: Effect of different treatments on biomass yield (g pot^{-1}) and B concentration in groundnut leaf

Soil	Av. B	Biomass yield (g pot^{-1}) Levels of boron (kg ha^{-1})							Bray's P yield (%)	B content in 3rd leaf in B control (mg kg^{-1})
		0	0.5	1.0	1.5	2.0	2.5	3.0		
1	0.35	54.6	61.0	83.7	132.10	105.5	93.1	92.30	41.33	11
2	0.72	72.0	78.5	81.8	80.0	76.0	75.0	70.0	88.0	23
3	0.80	75.0	80.6	83.0	82.0	78.0	78.0	68.0	90.0	24
4	0.42	60.8	82.4	85.6	135.5	110.0	102.5	95.3	44.9	15
5	0.85	70.0	70.7	70.0	68.5	68.0	65.0	60.0	99.0	25
6	0.55	65.0	75.5	77.0	78.0	72.0	68.5	68.0	83.0	20
7	0.34	55.0	60.0	84.0	128.4	106.0	94.0	90.8	42.8	12
8	0.81	71.0	76.0	77.0	76.0	75.5	70.0	68.0	92.0	26
9	0.53	51.0	65.0	115.0	125.8	110.5	98.4	98.0	40.5	14
10	0.57	71.0	75.0	79.5	80.0	78.5	77.0	75.0	89.0	21
Range	0.34–0.85	54.6–75.0	60.0–82.4	70.0–115.0	68.5–135.5	68.0–110.5	65.0–102.5	68.0–98.0	40.5–99.0	11–26
Mean	0.59	64.54	72.47	83.66	98.63	88.0	82.15	78.54		19.1
SD		8.60	7.99	11.93	27.72	17.53	13.58	13.99		5.6

Table 4: Effect of different treatments on biomass yield (g pot^{-1}) and B concentration in potato leaf

Soil	Av. B	Biomass yield (g pot^{-1}) Levels of boron (kg ha^{-1})							Bray's P yield (%)	B content in 3rd leaf in B control (mg kg^{-1})
		0	0.5	1.0	1.5	2.0	2.5	3.0		
1	0.35	278.0	300.0	320.0	350.0	357.0	348.0	315.0	77.9	20
2	0.72	347.0	360.0	400.0	408.0	395.0	390.0	320.0	85.0	28
3	0.80	300.0	340.0	370.0	400.0	360.0	350.0	310.0	75.0	30
4	0.42	283.0	320.0	360.0	400.0	457.0	340.0	305.0	62.0	22
5	0.85	310.0	320.0	328.0	335.0	320.0	318.0	315.0	92.0	32
6	0.55	300.0	350.0	380.0	410.0	462.0	405.0	320.0	65.0	24
7	0.34	262.0	310.0	375.0	390.0	405.0	410.0	318.0	64.0	15
8	0.81	377.0	410.0	428.0	433.0	400.0	360.0	302.0	87.0	33
9	0.53	295.0	310.0	325.0	385.0	410.0	360.0	325.0	72.0	23
10	0.57	333.0	365.0	382.0	410.0	450.0	390.0	340.0	74.0	25
Range	0.34–0.85	262.0–377.0	300.0–410.0	320.0–428.0	335.0–433.0	320.0–462.0	318.0–410.0	302.0–340.0	64.0–92.0	15.0–33.0
Mean	0.59	308.5	338.5	366.8	392.1	401.6	367.1	317.0		25.2
SD		34.74	33.66	34.67	29.39	46.62	30.23	10.73		5.63

same group of soils responded to higher dose of B application in case of potato where maximum yield was recorded at 2.0 kg B ha^{-1} level. The biomass yield of rice and groundnut in B control treatment was 95.64 and 64.54 g pot^{-1} and increased to 119.59 and 98.63 g pot^{-1}, respectively at 1.5 kg B ha^{-1} level. On the other hand, potato biomass yield was 308.5 g pot^{-1} in B control treatment and increased to 401.6 g pot^{-1} when the received B @ 2.0 kg ha^{-1}. This indicated that B requirement of potato is higher than rice and groundnut. At optimum dose of B application the biomass yield was increased over B control by 25% in rice, 52.8% in groundnut and 30% in potato. The response of different crops to B application at 0.5-2.5 kg B ha^{-1} in soils of Bihar, Punjab, Odisha, West Bengal, Assam was reported by Ali (1992) and Takkar (1996).

The mean available boron content in soils was 0.59 mg kg^{-1}. The graph plot of Bray's percent yield against soil available B revealed 0.56, 0.52 and 0.56 mg kg^{-1} as critical concentration of B in soil for rice, groundnut and potato, respectively. Similarly the B concentration in leaf revealed that the critical concentration of B in rice, groundnut and potato crop was 23, 19 and 26 mg kg^{-1}, respectively.

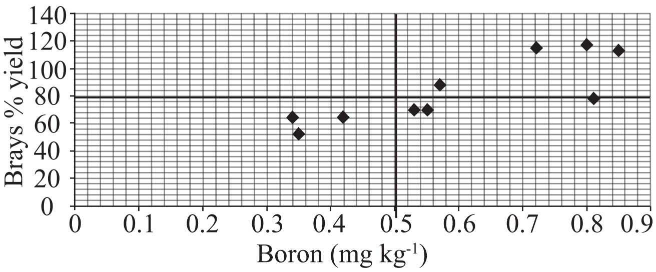

Figure 1: Scattered diagram of dry matter yield (%) of rice and available B in soil

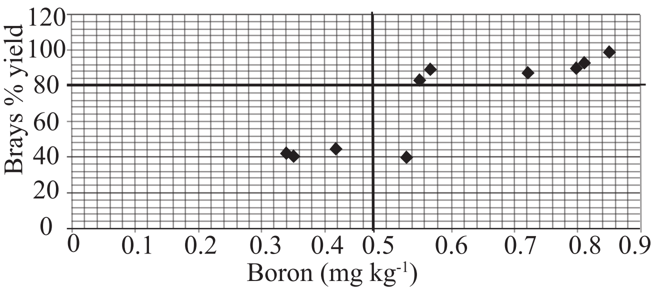

Figure 2: Scattered diagram of dry matter yield (%) of groundnut and available B in soil

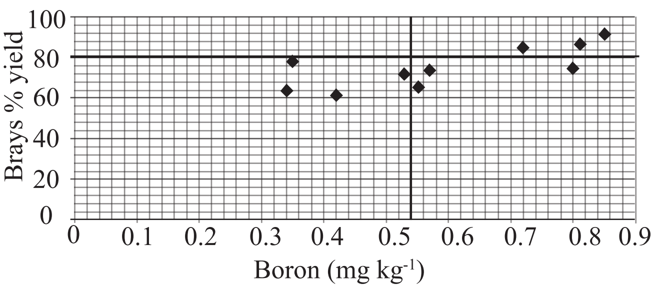

Figure 3: Scattered diagram of dry matter yield (%) of potato and available B in soil

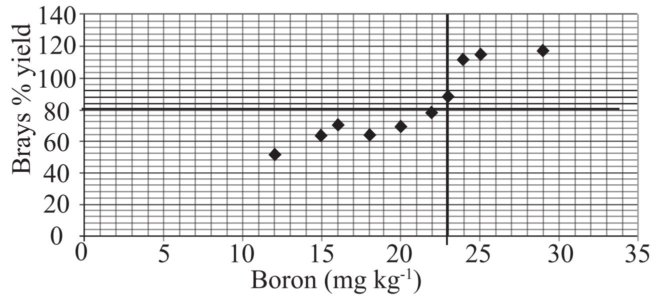

Figure 4: Scattered diagram of dry matter yield (%) and B content in 3rd leaf of rice

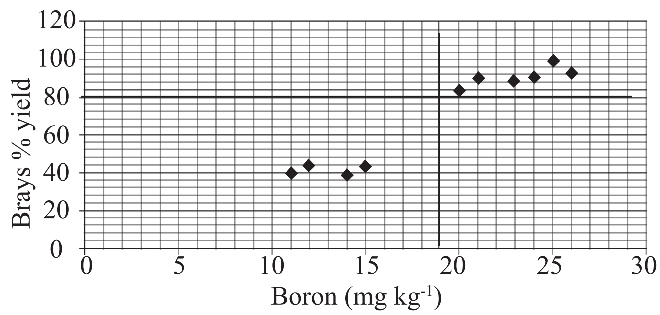

Figure 5: Scattered diagram of dry matter yield (%) and B content in 3rd leaf of groundnut

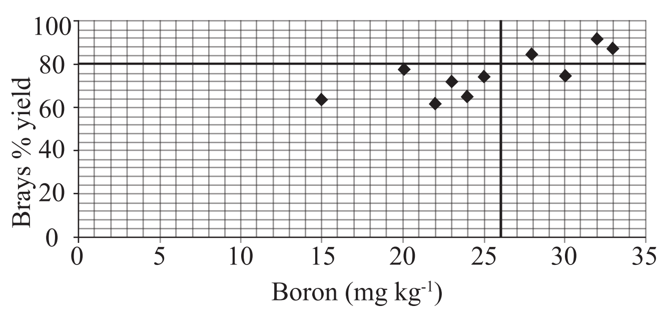

Figure 6: Scattered diagram of dry matter yield (%) and B content in 3rd leaf of potato

4. Conclusion

Critical limit of rice and potato was higher than groundnut indicating that groundnut requires more B than the other crops in red and laterite soils. Based on the critical limit of B, the fertility rating and recommendations need to be modified for the crops grown in red and laterite soils.

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