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Assessment of critical limits of Boron in potato growing soils of West Bengal

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ABSTRACT

Potato is one of the cheapest sources of energy-rich natural nutritive foods containing ample starch, sugar and protein, and carotene, phenol and ascorbic acid in minute quantities. Potato is an important vegetable and staple food crop in India after rice and wheat. A greenhouse experiment on potato, in which ten kilograms of soil was placed in a polyethene-lined earthen pot, was conducted on each of the soils of twenty-three different locations. The NPK recommended dose was applied at the rate of 200, 150 and 150 kg ha^{-1} in the form of G.R. grade reagent quality of Urea, Single Super Phosphate and Muriate of Potash to avoid any Boron (B) addition through them. The half N and full quantities P and K were applied as basal doses, and the rest of N was applied in two equal split doses - one at 20 and another at 35 days after sowing. The treatment combination of B application in the form of Boric Acid ($H_3BO_{3)}$ reagent grade in the pot experiment was like the following: B_0: 0 kg B ha^{-1}, $B_{1.0}$: 1 kg B ha^{-1}, $B2_{.0}$: 2kg B ha^{-1}, $B_{4.0}$: 4 kg B ha^{-1}. The critical limit of B in soil for the B nutrition of potato plants was determined following both the graphical and statistical methods of Cate and Nelson (1965 and 1971). We used Bray % Yield (BPY) of potato (leaf and tuber) and available B concentration of initial soils (before sowing) of 15 sites for estimating the critical value of available B. The result indicated that in respect of potato cultivation, B concentration below 0.48 mg kg^{-1} would show a deficiency of B. Below this concentration of B would be considered as a deficiency of B concentration in potato shoot which would influence to reduce yield and quality of potato.

Keywords: Critical limit, Bray % Yield (BPY), pot experiment

INTRODUCTION

Boron is an essential micronutrient element required for the nutrition of crops. This element has been reported to be deficient in most of the field-grown crops, including vegetables from different parts of the world (Chiba *et. al.*, 2009). India is the second largest producer of potato (*Solanum tuberosum* L.), next to China in potato production (45.3 million tonnes) in the world with an average yield of 22.8 t ha^{-1} (Mondal *et al.*, 2015). There is a wide variation in the agroecological condition of different parts of the country, which results in wide variations in the productivity levels of potato in different states. West Bengal ranks second among all potato-growing states in India with a production of 12.0 million tonnes from 0.41 million ha, while the productivity was 29.7 t ha¡1 during 2013 14 (Horticulture Statistics Division, GOI 2014). However, the productivity of potato in the soils is low due to multi-nutrient deûciencies and other allied problems (Banerjee *et al.*, 2016). Even in several places, the normal yield of crops could not be achieved despite balanced use of NPK due to micro-nutrient deûciency in soils (Sathya *et al.* 2009). The critical level of a nutrient refers to the soil or tissue concentration of that nutrient below which the crop will readily respond to its application. Critical level varies with soil, crop and extractant used. Again, the range between the deficient and toxic levels of B in soils and plants is very narrow (Nyomora *et al.*, 1997). Its application, even slightly above the optimum level, proves toxic to plants. This emphasizes the need to assess critical levels of B in the soil and plant tissues for judicious use of B as fertilizers. An attempt has been made here to determine the critical limit of B for potato plants and fine textured, acidic to slightly alkaline alluvial soils growing the crop intensively in West Bengal.

MATERIALS AND METHODS

Soil analysis

Surface (0-0.20 m) soil samples from fifteen different locations of intensively potato growing areas in West Bengal were collected and were air-dried, ground and passed through a 2-mm nylon sieve. The soils were analyzed for pH (Jackson, 1973) and organic C (Walkley and Black, 1934). Available B in the soil was extracted in 0.02M hot $CaCl_2$ solution (Parker and Gardner, 1981). The concentration of B in the filtrate was determined spectrophotometrically by the azomethine-H method of Wolf (1971) with slight modifications as suggested by Gupta (1979).

Pot experiment

Potato was selected as a B-responsive crop in the existing cropping systems in the new alluvial zone of West Bengal for identifying critical limits of B in potato-growing soils. Pot experiment, in which ten kilograms of soil was placed in a polythene-lined earthen pot, was conducted on each of the fifteen soils. They were treated with NPK at the rate of 200, 100 and 100 kg ha^{-1} in the form of GR grade reagent quality of urea, KH_2PO_4 and KCl to avoid any B addition through them. The half N and full quantities P and K were applied as basal doses, and the rest of N was applied in two equal split doses - one at 20 and another at 35 days after transplanting of seedlings. The soils in the pots were then moistened to field capacity with deionized water and were sown of potato (cv. *Kufri Jyoti*) in each pot, separately. Thereafter, the soils were treated with 0, 0.5, 1.0 and 2.0 mg B kg^{-1} (or 0, 1.0, 2.0 and 4.0 kg B ha^{-1}) of soils through reagent grade boric acid. There were always three replications for each of the soils and levels of added B. Irrigation was given, as and when required, using deionized water.

The critical limits were worked out through the Graphical and Statistical procedures proposed by Cate and Nelson (1965 and 971) using yield, relative yield, Bray's per cent yield, concentration and relative concentration of B, uptake and relative uptake of B etc., as the goal variables. The Bray's per cent yield (BPY) was calculated using the following formulae:

$$BPY = \frac{\text{Yield without nutrient}}{\text{Yield with optimum nutrient}} \times 100$$

Graphical method

Soil test values (x-axis) were plotted against BPY (y-axis). A pair of perpendicular lines were drawn, one line 5 cm from and parallel to the y-axis and the other 10 cm from and parallel to the x-axis. The four resulting sectors on the overlay were marked '-' for the bottom right and upper left and '+' for the bottom left and upper right. The overlay was moved horizontally and vertically on the graph always with the two lines parallel to the respective axes on the graph until the number of points showing through the plastic overlay in two '+' quadrants was at maximum. The position of the lines on the overlay in that condition is transferred to the graph, and the point where the vertical line crosses the x-axis was taken as the critical soil test level. In a similar way, the plant concentration was placed on the x-axis and BPY on the y-axis to get the critical levels of B in plant tissues.

Statistical method

The data were ordered in an array based upon the ranking of X values, i.e., soil test values. The (X, Y) pairs were maintained in this order throughout the analysis. Starting with the X value that will place two or more points to the left of a vertical dividing line, one then calculates the corrected sums of squares of the deviations from the means of the two 'population' that results from moving each successive X value. The sum of the two corrected sums of squares at each X level was then determined, and this pooled sum of squares was subtracted from the total corrected sum of squares of deviations from the overall mean of all Y observations. The difference between the pooled sum of squares and the total corrected sum of squares (the 'between groups' sum of squares) is then expressed as a percentage of total corrected sums of squares or as R^2 since this difference represents the additional explanation obtained by fitting two means rather than one.

Table 1. Amount of B extracted (mg kg^{-1}) by Hot-$CaCl_2$ of the experimental soils

Sites	pH	O.C. (%)	Available B (mg kg^{-1})
Baliguri	7.11	0.56	0.53
Dinhata	6.38	0.50	0.48
Krishnanagar	6.51	0.53	0.52
Phulbari	6.12	0.55	0.45
Polba-PS	4.95	0.63	0.46
Mahesdanga	5.08	0.57	0.41
Chakda	5.95	0.42	0.44
Satgachia	5.81	0.38	0.50
Adisaptogram	7.01	0.60	0.38
Moinaguri	6.36	0.54	0.50
Kandi	7.26	0.42	0.52
Mathavanga	6.20	0.71	0.60
Falakata	6.75	0.94	0.48
Beldanga	7.45	0.64	0.78
Memari	6.50	0.59	0.61
Range	5.08-7.45	0.42-0.94	0.41-0.78
Mean	6.36	0.68	0.59

RESULTS AND DISCUSSION

Extractable B content in the experimental soils

The amount of B extracted by hot calcium chloride varied from 0.41 to 0.78 mg kg^{-1} with a mean value of 0.50 mg kg^{-1} (Table 1). The hot-$CaCl_2$ extractable B content of these soils was higher than that obtained in some alluvial entisols, ranging from 0.10 to 0.33 mg kg^{-1} with a mean value of 0.20 mg kg^{-1} (Sarkar *et al.*, 2008).

Yield and yield-related characteristics of potato

Results showed that B application increased the fresh yield of potato leaf and tuber. On average, increases in leaf yield were 8.5, 8.9 and 5.6% (Table 2), whereas curd yield was 12.1, 28.1 and 12.7% (Table 3) with 1.0, 2.0 and 4.0 kg ha^{-1} of added B over the control, respectively. Results thus indicated that response was more pronounced with 2.0 kg B ha^{-1} than lower (1.0 kg ha^{-1}) and higher (4.0 kg ha^{-1}) levels of B application. Such a lower response to B application at 4.0 kg B ha^{-1} may be due to B toxicity to potato plants. In a study, Sarkar et al. (2006) observed that B application increased potato tuber yield from 5.0 to 16.2% in B-deficient red soils of Jharkhand. An increase in yield and yield components in low B soils with B application to mustard (Chaudhary and Shukla, 2004; Sarkar *et al.*, 2006), and wheat (Zada and Afzal (1997) were also reported.

The Bray's per cent yield (BPY) of potato for both leaf and tuber was computed based on the optimum response of B application. The BPY of leaf and curd varied from 52.6 to 120.6 and 47.8 to 109.5%, with a mean value of 79.7 and 74.9% (Table 2 and 3), respectively. The few sites showing higher BPY of leaf and tuber were characterized by relatively higher amounts of extractable soil B.

Boron concentration

Boron application significantly increased B

Table 2. Effect of different levels of B application on leaf yield of potato (g plant^{-1}) and Bray's per cent yield (BPY)

Sites	Levels of B application (mg kg^{-1})				BPY
	B_0	$B_{1.0}$	$B_{2.0}$	$B_{4.0}$	
Baliguri	90.0	105.0	136.7	120.0	65.9
Dinhata	136.7	113.3	110.0	113.3	120.6
Krishnanagar	176.7	139.0	143.3	243.3	72.6
Phulbari	113.3	145.0	190.0	140.0	78.2
Polba-PS	130.0	123.3	136.7	170.0	76.5
Mahesdanga	176.7	143.3	246.7	106.7	71.6
Chakda	150.0	160.0	120.0	190.0	78.9
Satgachia	86.7	163.3	150.0	126.7	53.1
Adisaptogram	96.7	93.3	153.3	103.3	63.0
Moinaguri	116.7	113.3	126.7	106.7	92.1
Kandi	100.0	173.3	140.0	190.0	52.6
Mathavanga	153.3	143.3	73.3	160.0	95.8
Falakata	136.7	120.0	106.7	116.7	113.9
Beldanga	160.0	153.3	136.7	123.3	104.4
Memari	130.0	230.0	156.7	53.3	56.5
Mean	130.2	141.3	141.8	137.6	79.7

B_0 = No B, $B_{1.0}$ = 1.0 kg B ha^{-1}, $B_{2.0}$ = 2.0 kg B ha^{-1} and $B_{4.0}$ = 4.0 kg B ha^{-1}.

Table 3. Effect of different levels of B application on tuber of potato (g plant^{-1}) and Bray's per cent yield (BPY)

Sites	Levels of B application				BPY
	B_0	$B_{1.0}$	$B_{2.0}$	$B_{4.0}$	
Baliguri	63.3	96.7	96.7	66.7	65.5
Dinhata	60.0	80.0	123.3	70.0	48.6
Krishnanagar	106.7	106.7	100.0	133.3	80.0
Phulbari	76.7	68.3	126.7	56.7	60.5
Polba-PS	93.3	166.7	136.7	140.0	66.7
Mahesdanga	103.3	103.3	170.0	160.0	60.8
Chakda	96.7	106.7	93.3	123.3	78.4
Satgachia	120.0	73.3	146.7	120.0	81.8
Adisaptogram	53.3	50.0	53.3	50.0	100.0
Moinaguri	76.7	60.0	70.0	60.0	109.5
Kandi	73.3	93.3	153.3	153.3	47.8
Mathavanga	83.3	143.3	86.7	83.3	58.1
Falakata	56.7	53.3	56.7	40.0	100.0
Beldanga	70.0	90.0	56.7	56.7	77.8
Memari	123.3	116.7	140.0	103.3	88.1
Mean	83.8	93.9	107.3	94.4	74.9

B_0 = No B, $B_{1.0}$ = 1.0 kg B ha^{-1}, $B_{2.0}$ = 2.0 kg B ha^{-1} and $B_{4.0}$ = 4.0 kg B ha^{-1}.

Table 4. Effect of different levels of B application to potato on B concentration (mg kg^{-1}) in whole plant harvested 30 days after transplanting

Sites	Levels of B application			
	B_0	$B_{1.0}$	$B_{2.0}$	$B_{4.0}$
Baliguri	28.5	35.5	47.3	52.7
Dinhata	31.2	33.7	38.4	45.2
Krishnanagar	28.9	38.9	38.8	53.4
Phulbari	21.1	23.3	35.1	48.4
Polba-PS	29.3	33.8	41.8	44.6
Mahesdanga	27.2	34.2	37.1	40.1
Chakda	23.1	28.8	37.8	56.1
Satgachia	23.6	38.4	46.5	61.9
Adisaptogram	24.1	27.7	30.8	35.1
Moinaguri	24.6	27.1	34.8	44.6
Kandi	37.5	39.2	44.1	52.1
Mathavanga	31.3	31.7	35.2	54.9
Falakata	22.4	30.7	34.7	37.1
Beldanga	23.5	33.4	34.4	44.0
Memari	27.2	30.3	40.5	47.7
Mean	26.9	32.4	38.5	47.9

B_0 = No B, $B_{1.0}$ = 1.0 kg B ha^{-1}, $B_{2.0}$ = 2.0 kg B ha^{-1} and $B_{4.0}$ = 4.0 kg B ha^{-1}.

concentration in the plants, irrespective of soils and stages of plant growth. The extent of plant B concentration increase in cauliflower was 20.6, 43.1 and 77.9% at 30 days after transplanting over the control with 1.0, 2.0 and 4.0 kg ha^{-1} levels of added B, respectively (Table 4). At the harvesting stage, the increases were 11.4, 26.5 and 46.0% in curd and 20.3, 43.7 and 69.8% in leaf over the control with 1.0, 2.0 and 4.0 kg ha^{-1} of added B, respectively (Table 5).

Critical limit of B

The critical limit of B in soil for the B nutrition of potato plants was determined following both the graphical and statistical methods of Cate and Nelson (1965 and 1971). The BPY of leaf and curd, relative concentration and relative B uptake data at the harvesting of potato were used for estimating the critical value of available B. Results (Fig. 1) showed that the critical values of B in soils as extracted by hot-$CaCl_2$ for B nutrition of potato considering BPY, relative B concentration and relative B uptake at harvest varied from 0.46 to 0.50 mg kg^{-1}. Therefore, an average of 0.48 mg kg^{-1} of these two (0.46 and 0.50 mg kg^{-1}) might be considered critical soil B-level extractable by HCC for the nutrition of potato in fine-textured alluvial soils of West Bengal.

Based on the critical values of extractable B, the experimental soils were grouped into two classes - below and above the critical limit for potato (Table 6). Out of 15 soils, five were below critical level, and eight were above critical level. Yield response was observed both below and above the critical level of soil test values for potato. The average increase in curd yield of potato below and above the critical limit was 23.0 and 15.2%, irrespective of the doses of B application.

The results of the present experiment showed that available B content in the soils taken for the experiment varied from 0.33 to 0.78 mg kg^{-1}. An increase in leaf and tuber yield of potato to B

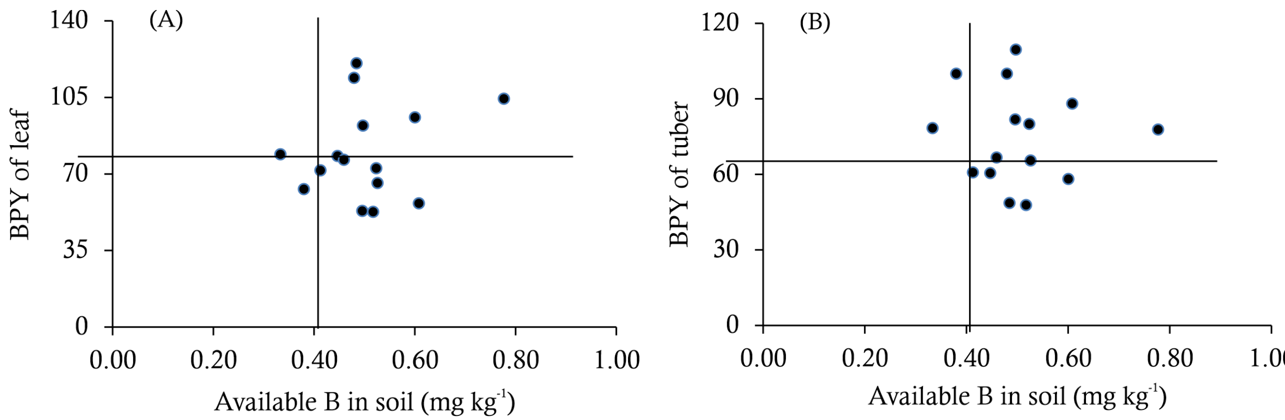

Fig. 1. Critical limit (*vertical lines* intercepting 'X' axis indicating the values) in hot-$CaCl_2$ extractable B for potato obtained by graphical method using BPY of leaf (A) and tuber (B)

Table 5. Effect of different levels of B application to potato on B concentration (mg kg^{-1}) in tuber and leaf at harvest

Sites	Harvest	Levels of B application (mg kg^{-1})			
		B_0	$B_{1.0}$	$B_{2.0}$	$B_{4.0}$
Baliguri	Tuber	17.2	18.7	19.5	19.6
	Leaf	20.9	25.1	26.7	27.6
Dinhata	Tuber	15.3	16.4	21.3	24.6
	Leaf	21.5	24.6	34.3	35.2
Krishnanagar	Tuber	17.7	18.8	23.1	24.0
	Leaf	17.0	22.7	28.4	30.4
Phulbari	Tuber	14.2	16.4	20.5	27.6
	Leaf	22.2	24.1	25.9	34.8
Polba-PS	Tuber	17.9	18.6	19.1	22.4
	Leaf	21.4	25.5	26.7	38.8
Mahesdanga	Tuber	17.8	18.7	19.5	21.8
	Leaf	20.8	28.2	31.5	42.3
Chakda	Tuber	15.5	18.6	19.7	22.4
	Leaf	17.7	23.2	29.1	34.3
Satgachia	Tuber	16.8	23.1	27.1	28.0
	Leaf	23.3	25.3	35.3	43.6
Adisaptogram	Tuber	16.0	17.4	21.0	25.1
	Leaf	22.6	23.0	26.3	33.7
Moinaguri	Tuber	15.9	16.5	18.8	27.3
	Leaf	18.7	21.3	24.1	27.1
Kandi	Tuber	16.5	19.3	21.4	22.8
	Leaf	19.1	25.9	41.9	43.6
Mathavanga	Tuber	15.6	17.9	20.5	22.8
	Leaf	18.6	29.0	29.7	37.3
Falakata	Tuber	17.8	20.8	20.1	23.9
	Leaf	21.8	22.6	25.5	27.5
Beldanga	Tuber	16.1	16.5	20.8	27.3
	Leaf	25.1	27.5	31.8	35.7
Memari	Tuber	22.4	23.9	27.2	29.0
	Leaf	21.0	26.9	30.6	37.3
Mean	Tuber	16.8	18.8	21.3	24.6
	Leaf	20.8	25.0	29.9	35.3

B_0 = No B, $B_{1.0}$ = 1.0 kg B ha^{-1}, $B_{2.0}$ = 2.0 kg B ha^{-1} and $B_{4.0}$ = 4.0 kg B ha^{-1}.

Table 6. Response (% over the control) of potato to B application in relation to critical B level in soil

Critical limit	No. of soils	Leaf yield response	Tuber yield response
< 0.48	5	35.0	23.0
> 0.48	8	22.1	15.2

application was recorded, and it was again supported by an increase in plant tissue B concentration and uptake of B with B application. The critical levels of hot-$CaCl_2$ extractable B in these soils were 0.48 mg kg^{-1} for the nutrition of potato.

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