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To evaluation of suitability of soil extractants for assessing boron availability to cauliflower (*Brassica oleracea*)

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Abstract

A pot experiment was conducted during 2015-2016 with twenty two numbers of soils of varying soil characters for selecting the most suitable chemical extractant for determination of available boron and evaluation of critical limits of boron for cauliflower. The soils were extracted with hot water, hot 0.01M calcium chloride, 0.01M tartaric acid, 1.0M ammonium acetate, 0.5M potassium dihydrogen phosphate and 0.1M salicylic acid. The availability of boron was found to be varying with chemical extractants used. In terms of the efficiency of B extraction, the extractants followed the order in decreasing trend as hot 0.01M calcium chloride (HCC) > hot water (HW) > 0.1M salicylic acid (SA) >0.5M potassium dihydrogen phosphate (PDP) > 0.01 M tartaric acid (TA) >1.0M ammonium acetate (AA). Critical limits of extractable boron as determined by graphical procedure were 0.50, 0.66, 0.45, 0.38, 0.47, 0.50 mg kg^{-1} and by statistical procedure were 0.53, 0.66, 0.47, 0.38 0.47 and 0.50 mg kg^{-1} for hot water, hot 0.01M calcium chloride, 0.01 M tartaric acid, 1.0M ammonium acetate, 0.5M potassium dihydrogen phosphate and 0.1M salicylic acid, respectively. Both the methods showed very closer values of critical soil boron concentration. Among the extractants, 0.1M salicylic acid recorded the highest correlation with Bray's percent yield, yield at control, B concentration at control and B uptake at control. Therefore, in view of high degree of correlation of soil test values with plant response parameters, 0.1M salicyclic acid was found to be the best extractant for assessing the available boron in soils of Assam. The critical level of boron concentration established by graphical and statistical procedures were 24.87 and 25.78 mg kg^{-1}, respectively grown in soils of Assam in cauliflower plant on dry weight basis at 60 days growth period.

Keywords: Cucumber, boron, yield, quality, konkan

Introduction

A number of extractants have been developed by soil chemists to assess the relative nutrient status of soils and to serve as the basis for making nutrient recommendations. Soil extractants like hot water, hot calcium chloride, mannitol, tartaric acid, salicylic acid, hydrochloride acid, ammonium acetate, Mehlich 1 and Mehlich 3 were evaluated and a wide range of soil B concentrations reported (Datta *et al*., 1996) [4]. In a given agro-climatic condition suitability of different soil extractant needs to be checked in predicting the response of a particular nutrient application (Watham *et al.,* 2014) [9].

Material and Method

Evaluation of suitable extractants for boron

The surface soil samples used for pot experiment were analyzed for available boron by using six extractants. The following six extraction procedures are given below:

Table: The following six extraction procedures are given below

Sl. No.	Extractants	Soil: extractant ratio	Shaking time (min)	References
1	Hot water	1:2	5 min reflux	Berger and Truog (1939)
2	Hot 0.01M $CaCl_2$	1:2	10	Aitken *et al*. (1987) [1]
3	0.01M $CaCl_2$	1:2	60	Aitken *et al*. (1987) [1]
4	1.0 M NH_4OAC (pH4.8)	1:2	60	Gupta and Stewart (1975)
5	0.5 M KH_2PO_4	1:2	60	Chao and Sanzolone (1989)
6	0.1M Salicylic acid	1:2	60	Datta *et al*. (1998) [3]

Hot water and hot $CaCl_2$ extracts of soils were prepared by refluxing 10 g soil in distilled water and $CaCl_2$ solution for 5 min and 10 min, respectively. Extractions with the remaining extractants were carried out with 10 g soil and 20 ml solution for 1 hour shaking on a shaker. The boron in extracted aliquot was determined by Azomethin-H colorimetric method John *et al*. (1975) [6].

Suitable extractant for extraction of boron was predicted on the basis of boron extraction from the soil and then assessed by examining the relationship between the amount of extracted boron and each of Bray's percent yield, plant boron concentration and boron uptake by cauliflower plants grown in control pot (without applied B).

Bray's percent yield was calculated as:

$$BPY = \frac{\text{Yield in control pot}}{\text{Yield at optimum level of B}} \times 100$$

Result and Discussion

Data regarding extractable B in soils of different zones are given in (Table 1). A relatively small range between deficiency and toxic limits of boron (B) necessitates precise evaluation of the availability of extractable boron before applying B in deficient soils. The results indicated that different extractants extracted the varying amount of boron from the soils. The extractants were arranged in decreasing order of the mean values of extractable B were HCC (Hot 0.01M calcium chloride) > HW (Hot water) > SA (0.1M Salicylic acid) > PDP (0.5M Potassium dihydrogen phosphate) > TA (0.01 M tartaric acid) > AA (1.0M Ammonium acetate).The variability in extractable B contents might be due to varying soil pH, organic carbon and parent materials on the one hand and the nature of extracting solution on the other. Hot 0.01M $CaCl_2$ (HCC) extractant extracted the highest amount of B among all extractants. Similar observations on the extraction of the highest amount of B as extracted by hot $CaCl_2$ is in agreement with the findings of (Datta *et al*., 1998) [3]. The highest amount of B extracted by HCC may be due to higher ionic strength. Aitken *et al*. (1987) [1] supported this observation by showing that HCC extracted more B than HW, ammonium acetate, tartaric acid and mannitol calcium chloride (MCC) from acidic soils of Queensland, Australia. Boiling the soil in solution (hot 0.01M $CaCl_2$) extracted comparatively more B than did other extractants as they extract not only inorganic soluble B but B from other pool like organic and adsorbed pool. The second highest extractant was HW and it extracted less amount of B than hot $CaCl_2$. This might be due to lower ionic strength than hot $CaCl_2$. The similar result was also reported by Sarkar *et al*. (2008) [8]. These results are in accordance with the findings of other researchers in which they revealed that the HWS- B consists of a non-specifically adsorbed B fraction and it is very feebly held by divergent soil constituents (particles). Consequently, with simple irrigation, this B fraction is released into soil solution and recognized as the most easily available B fraction for plant uptake Renan and Gupta (1991). The 10-min refluxing time of hot calcium chloride (HCC) compared to 5-min hot water (HW) extraction and higher ionic strength possibly could explain this difference. The amount of B extracted with tartaric acid (TA) was higher than that removed by ammonium acetate (AA), because TA was reported to be capable of complexing H_3BO_3 (Acree, 1971; Kustin and Pizer, 1969). Salicylic acid (SA) extracted the almost similar amount of B as removed by HW. The chemistry of B suggests that B may form salicylate complex with salicylic acid Cotton and Wilkinson, 1988). Among the extractants, 1.0M NH_4OAC extracting solution extracted the lowest amount of B. There is little evidence in the literature indicating that NH_4OAC can complex with boric acid. The use of NH_4OAC at pH 4.8 is considered to extract B by dissolving calcite surface in calcareous soils Cartwright *et al*. (1983) [2], which may be the reason that B removed by this extractant is lowest since most of the soils under present study are acidic.

Table 1: Amount of boron (mg kg^{-1}) extracted by different extractants

Soil no	Hot water (HW)	Hot 0.01M Calcium chloride (HCC)	0.01M Tartaric acid (TA)	1.0M Ammonium acetate (AA)	0.5M Potassium dihydrogen phosphate (PDP)	0.1M Salicylic acid (SA)
S_1	0.67	0.66	0.53	0.50	0.42	0.45
S_2	0.80	0.96	0.44	0.44	0.56	0.62
S_3	0.74	0.80	0.67	0.33	0.40	0.40
S_4	0.38	0.60	0.17	0.24	0.32	0.38
S_5	0.52	0.57	0.56	0.67	0.42	0.48
S_6	0.89	0.88	0.40	0.64	0.68	0.90
S_7	0.30	0.44	0.33	0.22	0.40	0.37
S_8	0.22	0.32	0.27	0.17	0.36	0.27
S_9	0.85	0.78	0.45	0.52	0.60	0.75
S_{10}	0.40	0.43	0.27	0.31	0.55	0.42
S_{11}	0.45	0.55	0.70	0.24	0.42	0.50
S_{12}	0.50	0.62	0.55	0.34	0.47	0.40
S_{13}	0.83	0.68	0.55	0.36	0.75	0.66
S_{14}	0.59	0.85	0.73	0.60	0.52	0.70
S_{15}	0.24	0.52	0.35	0.20	0.27	0.46
S_{16}	0.26	0.32	0.36	0.24	0.41	0.25
S_{17}	0.51	0.68	0.57	0.41	0.38	0.75
S_{18}	0.78	0.95	0.45	0.54	0.70	0.78
S_{19}	0.76	0.48	0.65	0.38	0.76	0.68
S_{20}	0.53	0.78	0.47	0.42	0.54	0.56
S_{21}	0.36	0.35	0.29	0.13	0.35	0.29
S_{22}	0.46	0.45	0.30	0.17	0.45	0.32
Range	0.22-0.89	0.32-0.96	0.17-0.73	0.13-0.67	0.27-0.76	0.25-0.96
Mean	0.55	0.62	0.46	0.37	0.49	0.52

Correlation study

All the six extractants were significantly and positively correlated with each other for measurable values of plant-available B (Table 2). A close relationship among different extractants suggested that these extractants extracted varying quantities of available boron but the degree of variation was closely related. The highest correlation was obtained between HWS and HCC. A similar observation was reported Niaz *et al*. (2013) [7].

Table 2: Correlation coefficient (r) among different extractants

	HW	HCC	TA	AA	PDP	SA
HW	1					
HCC	0.814**	1				
TA	0.543**	0.428*	1			
AA	0.777**	0.725**	0.487*	1		
PDP	0.735**	0.470*	0.312	0.519*	1	
SA	0.806**	0.761**	0.443*	0.748**	0.700**	1

* Significant at 5% level, ** Significant at 1% level

All the extractants exhibited significant positive correlation with organic carbon, CEC and clay except TA. The positive correlation between organic carbon and boron extracted by different extractants is due to their colloidal natures which adsorb boron ion exchange sites. Soil organic matter plays an important role in B availability by minimizing B leaching and maintaining B in a relatively available form. Similar finding was reported by Datta (1998) [3] and Gupta *et al*. (2016) [5]. All extractants correlated significantly and positively with clay content (Table 3). The contribution of clay content towards adsorption sites for anions is responsible for positive correlation with extractable boron.

Table 3: Correlation coefficients (r) between soil B extracted by various extractants and soil properties

Extractant	pH	OC (%)	CEC cmol(p+) kg^{-1}	CLAY (%)
HW	0.067		0.715**	0.670**
HCC	0.046	0.606**	0.699**	0.630**
TA	0.192	0.178	0.149	0.167
AA	-0.142	0.587**	0.528*	0.438*
PDP	0.180	0.636**	0.464*	0.624**
SA	0.158	0.735**	0.509*	0.586**

* Significant at 5% level, ** Significant at 1% level

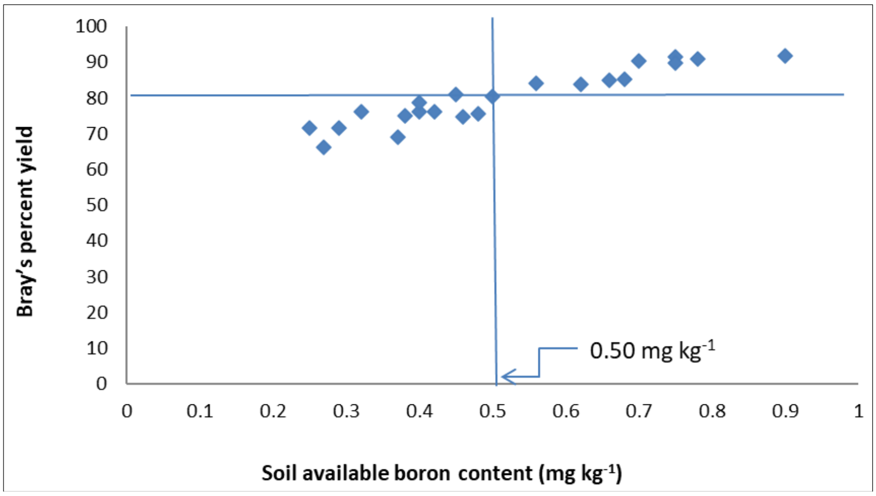

Fig 1: Scatter diagram of 0.1M Salicylic acid vs Bray's percent yield of cauliflower

Table 4: Plant boron concentration, Bray's per cent yield and predictability values (R^2)

Sr. No.	Soil boron in population-I Boron concentration at control	Bray's % yield	Mean Bray's % yield in population -I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population -II	Corrected sum of squares of deviation from mean of population CSS-II	R^2 TSS - (CSSI-CSSII) / TSS
1	17.6	66.32			80.23	1238.89	0
2	17.85	69.19	67.75	4.10	80.89	1036.20	0.160
3	18.33	71.57	69.02	13.79	81.48	892.24	0.269
4	19.12	71.58	69.66	18.68	82.00	788.81	0.348
5	19.28	74.80	70.69	39.77	82.58	674.13	0.424
6	19.29	75.12	71.43	56.12	83.04	609.97	0.462
7	20.23	75.51	72.01	70.42	83.53	543.36	0.505
8	20.86	76.03	72.51	84.53	84.07	474.73	0.549
9	21.18	76.15	72.92	89.07	84.64	405.47	0.601
10	21.67	76.23	73.25	106.13	85.30	327.74	0.650
11	22.29	78.83	73.76	134.41	86.05	238.67	0.699
12	24.87	80.42	74.31	175.09	86.71	181.72	0.712
13	25.78	80.95	74.82	215.74	87.34	138.18	0.714
14	25.95	83.92	75.47	292.64	88.05	92.80	0.689
15	26	84.03	76.04	360.93	88.56	73.64	0.649
16	26.13	84.95	76.60	435.36	89.21	50.11	0.608
17	26.53	85.24	77.11	505.67	89.92	28.94	0.568
18	31.61	89.70	77.81	655.52	90.86	2.65	0.469
19	31.67	90.39	78.47	805.63	90.39	3.25	0.347
20	31.77	91.02	79.10	955.29	91.40	0.23	0.229

21	33.33	91.50	79.69	1101.81	91.59	0.01	0.111
22	33.55	91.67	80.23	1235.01			
						SS	142856.79
						TSS	1238.89
						CF	141617.89

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