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Establishment of critical boron limits for castor (*Ricinus communis*) in red sandy loam soil with various boron extractants

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In many parts of India, widespread deficiencies of boron (B) nutrient in various soils and response to B application by oilseed crops were observed (Chaudhary and Shukla 2004, Rego *et al*. 2007, Sekhawat *et al.* 2008, Murthy and Padmavathi 2010, Mandal and Das 2011). Boron toxicity occurs on agricultural lands when it has been added in excessive quantities, for example, with fertilizer materials, irrigation water, or coal ash. The range of deficiency and toxicity limit of B in soils for many crops are narrow. Thus, management of soils and evaluating the B status of soils is of utmost importance. Several soil-test procedures employing chemical extractants have been suggested for determining plant available B from soil and for predicting response of crops to applied B (Chaudhary and Shukla 2004). The relevance of a particular method in assessing B supplying capacity of soils depends on their physical and chemical characteristics. Castor (*Ricinus communis* L.) is an important oilseed crop of the semi-arid region of India, which is responsive and sensitive to B deficiency (Rego *et al*. 2007, Murthy and Padmavathi 2010).

The most commonly used method is hot water (Berger and Truog 1939) or its variants, such as hot 0.01 M $CaCl_2$ now favoured in most laboratories. Also, 0.05 M HCl, mannitol + sorbitol, and salicylic acid has been suggested as extractants for soil B. While all extractants may have a place in testing for plant available B on some soils, such confirmation needs to be completed for a particular crop-soil combination. The usefulness of an extractant can be determined only when the soil test values correlate aptly with the crop response. Rego *et al*. (2007) employed hot water to extract available B in semi-arid tropical (SAT) soil to study the response of castor crop. For some acid soils of West Bengal, hot 0.01 M $CaCl_2$ was found apposite extractant for assessing available B and the suitability order was: hot 0.01M $CaCl_2$ > hot water > 0.1M salicylic acid and 1N NH_4OAc (pH 4.8) (Datta *et al*.1998). Thus, there is no universal extractant for predicting available B, for soils of diversified physical and chemical characteristics. Selection of a promising extractant for a particular soil needs careful consideration. The present investigation was aimed i) to select the most promising extractant to predict available B to castor grown on semi-arid soils of Andhra Pradesh; ii) to find out critical B level in soils with various extractants and B content in recently matured leaves of castor and iii) to find out the best-fit fit equation to explain the critical limits.

A field experiment was conducted with castor (*cv*. 48-1) as test crop during the rainy season of 2010 to find out critical B level in red sandy loam (Alfisols) soil of the semi-arid tropical region of Andhra Pradesh. The physico-chemical properties of the experimental soil are pH: 7.3, E.C. 0.23 dS/m, C.E.C. 29.5 c mol (p+)/kg and org. C. 0.25%. Available N, P (P_2O_5) and , K (K_2O) were 200, 16 and 210 kg/ha, respectively and hot water soluble B 0.4 mg/kg. Soil texture was sandy loam with 13.5% clay content and non calcareous in nature. Kaolinite is the dominant clay mineral. The treatments comprised 7 B levels, viz. 0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3 kg/ha supplied through borax. Recommended dose of NPK (60:40:30 kg/ha) was applied. Recently matured leaf (RML) samples positioned on the primary spike from the top were collected at 65 days after sowing (DAS). Initial and at 30 DAS soil samples were collected and processed. Eight extractants, viz. hot water, hot 0.01M $CaCl_2$, Morgan, 0.01M $CaCl_2$ + 0.05M mannitol (pH 8.5), 1M NH_4OAc (pH 4.8), 0.05M mannitol (pH 9.8), 0.2M sorbitol+1N NH_4OAc+0.1M TEA (pH 7.3), 0.2M mannitol+1N NH_4OAc+0.1M TEA (pH 7.3) commonly used for estimating B, were evaluated and B in soil extracts and in RML of castor were tested using the azomethine-H colourimetric method (Wolf 1971). The use of eight extractants for finding out available soil B was assessed by correlating the extractable B in soil with relative percent

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seed yield and B content in recently matured leaves (RML) of castor. Linear, Quadratic, exponential and lowess smoothing equations were fitted to find out critical soil available B and in RML of castor B.

The various extractants used in the present study differed widely in the B extracted (Table 1). The results show that hot water and 0.2M mannitol + 1N NH_4OAc + 0.1M TEA (pH 7.3) extracted relatively more B than other extractants which corroborate well with the observations of Rego *et al* (2007). Hot water extractants known to extract the free form of B and not the one complexed with organic matter. The B extracted by these extractants was in the following descending order: hot-water > 0.2M mannitol+1N NH_4OAc+0.1M TEA (pH 7.3) > hot 0.01M $CaCl_2$ > Morgan > 0.05M mannitol (pH 9.8) > 0.2M sorbitol+1N NH_4OAc+0.1M TEA (pH 7.3) > 1M NH_4OAc (pH 4.8) > 0.01M $CaCl_2$+0.05M mannitol (pH 8.5). Among the chelating extractants, the higher amount of B was extracted by 0.2M mannitol+1N NH_4OAc + 0.1M TEA (pH 7.3) than 0.2M sorbitol + 1N NH_4OAc + 0.1M TEA (pH 7.3). The difference in B extractability by chelating extractants could be explained based on functional groups involved in chelating B. Mannitol and sorbitol have dihydroxyl functional groups that form a ligand with B and these groups are more effective in extracting B. Mannitol known to complex B only when soil pH is greater than 8.0. In the present study, soil pH was 7.3 probably for the same reason the B extracted with this reagent combination was also lowest.

Castor seed yield varied from 694 to 931.2 kg/ha under rainfed conditions. Oil content did not show any significant variation among the B treatments. However, an increase in oil content of rape was reported due to the application of recommended dose of NPK + 5 tonnes organic manure + 0.5 kg B/ha as Calbor by Mandal and Das (2011).

Simple correlation coefficients of the B extracted by different extractants and relative seed yield percent and B content in castor leaves were calculated. Based on the studies, the best suitable extractants for castor crop in semi-arid soils were hot water (0.49**) and 0.2M mannitol+1N NH_4OAc+0.1M TEA (pH 7.3) (0.47**) because of their significant correlation. Apparently, these extractants have extracted the plant available B form from soil. Suitability of an extractant is determined only when the soil test values correlate aptly with the crop response. The critical levels of B in soil estimated by drawing scatter diagram with various extracants were 0.65 for hot water, 0.35 for hot 0.01 M $CaCl_2$, 0.33 for Morgan, 0.12 for 0.01M $CaCl_2$+0.05M mannitol (pH 8.5), 0.16 for 1M NH_4OAc (pH 4.5), 0.23 for 0.05M mannitol (pH 9.8), 0.020 for 0.2M sorbitol+1N NH_4OAc+0.1M TEA (pH 7.3), 0.55 for 0.2M mannitol+1M NH_4OAc+0.1M TEA (pH 7.3). The HWS-B critical level to delineate B responsive and nonresponsive soils of SAT was 0.50 mg/kg (Rego *et al*., 2007). The critical HWS-B observed in the study is slightly higher, which can be ascribed to the crop, plant part and soil type. Recently, Murthy and Padmavathi (2010) reported 0.67 mg/kg as a critical HWS-

Table 1 Critical boron limits (mg/kg) established with different extractants in red sandy loam soil (Alfisol) and in recently matured leaves of castor (cv. 48-1)

Extractant	Soil boron (mg/kg)					
	vs Relative seed yield of castor (%)	*vs* RML-B	Quadratic	Linear	Exponential	Mean available soil B mg/kg
Hot water	0.65 (90.0)	0.67 (90.1)	0.76 (90.2)	0.79 (90.1)	0.85	0.57
Hot 0.01M $CaCl_2$	0.35 (68.0)	0.35		0.75 (90.2)	0.74 (90.0)	0.30
Morgan	0.33 (90.0)	0.37				0.29
0.01M $CaCl_2$+0.05M mannitol (pH 8.5)	0.12 (0.85)	0.12 (91.2)	0.18			0.09
1M NH_4OAc (pH 4.8)	0.16 (90.0)	0.16				0.13
0.05M mannitol (pH 9.8)	0.23 (90.0)	0.24				0.22
0.2M sorbitol+1N NH_4OAc +0.1M TEA (pH 7.3)	0.20 (87.0)	0.18 (89.4)		0.23		0.19
0.2M Mannitol+1M NH_4OAc +0.1M TEA (pH 7.3)	0.55 (85.0)	0.54 (90.4)	0.525 (90.2)	0.615		0.53

Relative seed yield percent at which critical level is determined is given in parenthesis

B level in red sandy loam soils with castor (cv. 48-1) as test crop. In literature, no data are available for the critical limits of boron extracted by chelating extractants for castor crop.

The critical B concentration in RML of castor was 31.1 mg/kg on the dry weight basis by scatter diagram technique. Nearly similar value was found by quadratic (32.5 mg/kg). However, linear (35.4 mg/kg) and lowess smoothing (37.0 mg/kg) equations gave slightly higher values. Earlier, Murthy and Padmavathi (2010) reported a critical limit of B content in RML of castor (cv. 48-1) as 39 mg/kg. Further, scatter diagram drawn between RML-B and soil-B as well as soil-B and relative seed yield percent for various extractants also gave nearly similar critical B limits.

To determine critical nutrient limits various linear and nonlinear equations were also used by the researchers besides scatter diagram technique. To determine critical B limit quadratic equation was used and it fitted well for the hot water, 0.01M $CaCl_2$+0.05M mannitol (pH 8.5) and 0.2M mannitol+1M NH_4OAc+0.1M TEA (pH 7.3) extractable B and relative seed yield percent of castor (Table 1). The linear equation fitted well for the hot water, hot 0.01M $CaCl_2$ and chelating agents. While, exponential equation suited well for hot water and hot 0.01M $CaCl_2$ only. The variation in critical values may be because of the inherent limitation of the equations.

SUMMARY

The hot water is continued to be the most reliable extractant for assessing available B in semi-arid red sandy loam textured soils of Andhra Pradesh. Considering the advantageous features of 0.2M mannitol + 1N NH_4OAc + 0.1M TEA (pH 7.3) extractant, and its simplicity compared to hot water and hot 0.01 M $CaCl_2$ methods, this extractant may be used to delineate the available B status of semi-arid red sandy loam soils on a routine basis where many samples are to be analysed. The critical B level found out by extractants, hot water was 0.65 mg/kg and 0.2M mannitol + 1N NH_4OAc + 0.1M TEA (pH 7.3) was 0.55 mg/kg. The critical B concentration in RML of castor was 31.1 mg/kg on the dry weight basis. Among the linear and nonlinear equations tried the critical B limits calculated by linear and quadratic could explain better.

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