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RESEARCH PAPER

Critical level of hot water soluble boron for predicting response of toria (*Brassica compestris*) in alluvial soils of Punjab

S.S. DHALIWAL*, U.S. SADANA AND J.S. MANCHANDA
Department of Soil Science, Punjab Agricultural University, LUDHIANA (PUNJAB) INDIA
(Email : drdhaliwalss@yahoo.com)

***Abstract* :** A screenhouse investigation was conducted on 20 soils to determine the critical deficiency limit of B in *Entisols* and *Inceptisols* for predicting response of toria with cultivar TL 15 to B application. Field investigation was also conducted at research farm area of Department of Soils, PAU, Ludhiana to confirm these results under field conditions. The soils selected for this study were having a wide range of hot water soluble boron (HWS-B), varying from 0.10 - 1.70 mg kg^{-1} soil. Depending upon response of toria to applied B, nine soils out of 20 were classified as B deficient whereas, eleven were grouped into B sufficient range. The results of our study predicted that HWS- B was significantly related with Bray's per cent dry matter yield. Soil application of B @ 0.44 mg kg^{-1} soil significantly increased the dry matter yield of toria over control and with application of B @ 0.22 and 0.88 mg kg^{-1} soil. However, increase in dry matter yield was not significant with increase in concentration of B beyond 0.44 mg kg^{-1}. Both statistical and graphical models of Cate and Nelson technique were employed for analysis of data which indicated that the critical level to be 0.51 mg kg^{-1} soil of HWS-B for prediction of B deficiency in the soils for toria crop. On the other hand the critical deficiency level in toria of 45 days toria plants was 29.2 mg kg^{-1}. The predictability of soil and plant critical limit for B was 94 per cent. These results were also confirmed in the field experiment which reported the equivalent results and similar response of toria crop to applied B @ 1.0 kg ha^{-1}.

***Key Words* :** Critical level, Green house experiment, Hot water soluble boron

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INTRODUCTION

Among different plant nutrients, boron (B) is an essential element for agricultural crops production and the major role of B in plants is the control of the membrane functions (Dale and Krystyna, 1994). The deficiency of B in agricultural crops especially toria (*Brassica compestris*) can lead to disorders in plant community which further leads to serious health problems. World production of toria has increased very rapidly over the last 20 years. Though, B deficiency is more prevalent on acid soils high in Fe and Mn oxides and on soils receiving high rainfall (Brown *et al.,* 2002) it may also appear in crops grown in alkaline soils where B becomes unavailable to plants. Toria cultivated in India 3000 years ago and it was introduced to China and Japan, about 500 to 200 BC (Krzymanski, 1998). The average yield of oilseed toria depends on a large number of factors such as climate of the area, soil fertility status, and intensity of production, fertilizer input, B content of soil and variety of toria cultivar. The average yields of toria shows a wide range from country to country. India is also an important producer of oilseed toria accounting for as much as 14 per cent of world production.

Boron deficiency symptoms in plants:

Boron plays a pivotal role in cell wall biosynthesis and in regulating membrane permeability, tissue differentiation, carbohydrate and protein metabolism, cell division and cell

* **Author for correspondence.**

elongation, pollen germination and pollen tube growth, ensuring adequate seed set in the pods which is important to achieve a high seed yield. Under B deficiency, pollen viability and seed set of toria is greatly reduced (Nyborg and Hoyt, 1970) and protein formation is also restricted. A lack of B in contrast to other nutrients is the only deficiency which accelerates physiological processes instead of reducing them. It seems that all B deficiency symptoms can be attributed to uncontrolled tissue proliferation such as increased cell division in the cambium without cell differentiation (Bussler, 1973) leading to abnormal cell growth and the bursting open of stems. The internodes of stems are stunted and the whole plant appears squat giving a bushy or rosette appearance. Toria leaves with lack of B are a pale green, in some cases with reddish discoloration and interveinal yellow mottling (Nyborg and Hoyt, 1970). The edges of younger leaves are unrolled. With continuing B shortage, new leaves are deformed and stems crack. The whole leaf blade growth is considerably reduced. Leaves at the base of the plant begin to die and at harvest most have already fallen from the plant. The abnormally thickened stems often show brown necrotic, corky lesions and cracks with a tendency to rupture. The stems are often hollow. Flowering appears restricted and distorted, the inflorescence is compact and irregular with infertile flowers. The buds and flower drop is typical. The number of pods and particularly seed set are greatly reduced with B deficiency.

Distribution of boron in soils:

Toria is included in those species which are characterized as sensitive to B deficiency and most responsive its application (Bergmann, 1992; Shorrocks, 1997). Moreover, toria crop is often cultivated on soils low in B (strongly weathered soils, course textured soils, shallow soils, thin soils over calcareous soils, volcanic ash soils) or where plant availability of B is reduced. For example as a consequence of high soil pH, liming and drought periods during the growth period, B availability is greatly reduced. For this reason B deficiency in toria crop is observed on a worldwide basis (Shorrocks, 1997). In marginal micronutrient deficient soils the determination of critical limits establishes useful information maintaining B deficiencies and disorders in crops. Jackson and Chapman, (1975) reported that many bean plants suffering from B deficiency showed decrease in root elongation, followed by degeneration of meristematic tissues, which was possibly due to limited cell division. In comparison to other crops, Brassica species have a relatively high B requirement and react sensitively to B deficiency. Among commonly recognized micronutrients, B deficiency is more commonly observed in B deficient light textured acidic *Entisols* and *Inceptisols* receiving high precipitation (Welch *et al.,* 1991; Brown *et al*., 2002). Under the acidic environment, soil solution B remains as non-ionized H_3BO_3 species having little tendency to be adsorbed unto negatively charged soil solids. Mandal and De, (1993) reported a wide range of B distribution in acidic *Inceptisols* of India whereas, Sarkar *et al.* (2007) observed different methods for increasing the efficiency of applied B for different crops. Malhi *et al.* (2003) and Sarkar *et al.* (2006) evaluated the feasibility of B fertilization in B deficient soils and its uptake in different soils. Parker and Gardner, (1981) reported the determination of hot water soluble boron in some acid oregon soils using a modified azomethine-H procedure (Parker and Gardner, 1981) and evaluated critical limits for different crops. The B content of normal soils ranged from 2-100 mg kg^{-1} with an average of 30 mg kg^{-1}. The B content of soils depends largely on type of parent material of soils. The low B content can be expected in those soils which are derived from acid igneous rocks. Coarse-textured soils with low organic matter exhibit more B deficiency. In fact the B deficiency occurs more frequently on over limed or alkaline soils than on acid soils which suggests the possible effects of Ca^{+2} and Mg^{+2} ions on B nutrition of soils (Hill and Morril, 1975).

Response of toria to boron fertilizer application:

Toria gives a yield response to B fertilization which corresponds to the extractable B content of the soil (Table 2). Xue *et al*. (1998) identified differences in B efficiency between *Brassica compestris* varieties with significant differences in leaf B concentration at the same site. Although there was not a very close relationship between B content in the leaves and yield response due to B fertilization, it could be concluded in these investigations on B deficient soils that a B content of 25-30 ppm B in the leaves was necessary to achieve maximum seed yield. Similar values were found in Pakistan on B deficient alkaline calcareous soils with 32 ppm B in whole shoots and 38 ppm B in most recently matured leaves (Rashid *et al*., 1994). In many experiments, toria showed a higher critical tissue B level with 49 ppm B in the leaves and a higher B fertilizer demand to achieve optimum seed yield. Very little research so far is conducted on B nutrition of green gram crop and its critical limits in soils and plants. Therefore, careful assessment of the status of B in different soils and to determine the critical limit of B in soils as well as plants for green gram in B deficient soil is of paramount importance in achieving the B nutrition, biomass yield and uptake of B in various types of soils.

MATERIALS AND METHODS

Twenty bulk soil samples (0-15 cm) representing a wide range in hot water soluble B were collected from Ludhiana district of Punjab. The soils belong to great group *Ustochrepts*. Each soil sample was air-dried and ground in a wooden mortar to pass through 2 mm sieve. The soils under study were loamy sand to sandy loam in texture, neutral to alkaline in reaction, pH 7.4 to 8.4. Also the soils were low to medium in organic carbon to 0.28 to 0.45 per cent and medium to high in available N (179 - 367 kg ha^{-1}) and P_2O_5 (14 to 22 kg

ha^{-1}) as well as low to medium in K (84 to 358 kg ha^{-1}). The hot water soluble B (HWS-B) in untreated 20 soils ranged from 0.10 to 1.71 mg kg^{-1} soil.

A screenhouse pot culture experiment was conducted with toria cultivar TL 15 as a test crop was sown in the first fortnight of September 2008. Each polyethylene-lined pot was filled with 4 kg of soil pretreated uniformly with a solution supplying 31 and 10 mg kg^{-1} soil of elemental N (urea) and P_2O_5 (superphosphate), respectively. Boron was added at the rate of 0, 0.22, 0.44 and 0.88 mg kg^{-1} soil as $Na_2B_4O_7.10H_2O$ (decahydrate sodium tetra borate) solution. There were three replicates. Ten healthy seeds of toria were sown in each pot and were thinned to five after emergence. The soil was initially adjusted to approximately 60 per cent of the saturation percentage moisture content and the pots were subsequently watered as and when required. In the glass house the plants were harvested at 45 days growth and washed with 0.1N HCI solution, rinsed with deionized water, dried at 65^o C and the oven-dried weight was recorded. 0.5 g of plant sample was dry ashed in silica crucibles in an electric furnace at 450^0C for 4 hours and ash was dissolved in 6N hydrochloric acid mixture and the B content was estimated in the clear aliquot by modified azomethine-H procedure (Parker and Gardner, 1981).

A field experiment was also conducted to verify the screenhouse results under field conditions. The soil of the experimental field was loamy sand in texture, low in available N, medium in P and K. TL 15 variety of toria was sown in the first fortnight of September 2009 with B levels of 0.0, 0.5, 1.0 and 2.0 kg ha^{-1}. The N and P were applied as recommended in the package of practices. The experiment was designed with randomized blocks with three replications. The plants samples were taken at 45 days growth and washed with 0.1N HCI solution, rinsed with deionized water, dried at 65^0C and the oven-dried weight was recorded. 0.5 g of plant sample was dry ashed in silica crucibles in an electric furnace at 450^0C for 4 hours and ash was dissolved in 6N hydrochloric acid mixture and the B content was estimated in the clear aliquot by modified azomethine-H procedure (Parker and Gardner, 1981). Toria yield data (straw and grain) were also recorded at maturity and collected samples were analyzed for B using the same procedure as used for 45 days old toria samples. The soils were analysed for texture, pH, and organic carbon, available N, P and K according to the standard procedures (Black, 1965). The soil texture was determined by the hydrometer method (Sur and Singh, 1976). Soil B was extracted by hot water soluble method (Parker and Gardener, 1981). Boron in the soil extracts and plant aliquots was determined by atomic absorption spectrophotometer.

Consequently, the dry matter yield and B uptake differed markedly (Table 1). In soils 1 to 9 the plants in check pots exhibited visible symptoms of B deficiency at the 25-day growth stage. Toria plants suffering from B deficiency showed decrease in root elongation, followed by degeneration of meristematic tissues, which was due to limited cell division. Bray's per cent yield as well as B uptake were chosen to evaluate the parameter of soil B availability and were calculated as:

$$\text{Bray's per cent yield} = \frac{\text{Yield or uptake without B}}{\text{Yield or uptake at optimum B}} \times 100$$

The critical deficiency level of B in soil and plant was determined by the procedure of (Cate and Nelson, 1965 and 1971).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of B fertilizer application in the green house experiment:

Soil critical deficiency level and response to B:

The mean increase in dry matter yield over control in B deficient soils (soil 1-9) varied from 3.17 to 8.02 g pot^{-1} with a mean value of 5.34 g pot^{-1}(Table 1). The mean increase in dry matter yield on soils with sufficient B was 3.20 g pot^{-1} indicating thereby that the deficient soils have 67 per cent more response than the sufficient soils. The B deficient soils with 0.44 mg kg^{-1} treatment gave higher dry matter yield compared with 0.22 and 0.88 mg kg^{-1} treatments (Table 4). Some of soils with deficient B levels (B less than 0.50 mg kg^{-1}) showed the low dry matter yield which might be resulted from less cell division and elongation in meristematic tissues and floral organs. Dell and Huang (1997) showed a direct relationship between biomass yield and B content in wheat leaves. Brown and Shelf (1997) and Brown *et al.* (2002) reported that dry matter yield of spinach plants was reduced by 20 per cent in B deficient soils as a result of reduction in cell elongation by 32 per cent. Hot water soluble boron (HWS-B) and toria dry matter yield were used to find critical limit of B for differentiating B responsive soils from B non-responsive soils. For this the HWS-B was significantly correlated by plotting Bray's per cent dry matter yield against HWS-B according to the graphical method of Cate and Nelson (1965). A value of 0.51 mg kg^{-1} of HWS-B in the soil differentiated B responsive soils from the non-responsive soils (Fig.1). Cox and Camprath (1972) reported a critical range of 0.10 to 0.70 mg kg^{-1} of HWS-B in soils for most crops. Dhaliwal and Manchanda (2009) reported a critical limit of 0.52 mg kg^{-1} for moong bean crop on a variety of soils. Baker and Cook (1956) observed that alfalfa required B fertilization when soil test indicated < 0.90 to 1.0 mg kg^{-1} HWS-B. Considering that a soil is responsive which gave 80 per cent of the maximum yield or more than that without B application is non-responsive to applied B. All the soils containing 0.51 mg kg^{-1} HSW-B or less responded to B application. This confirmed that the soils under investigation were B deficient (Table 1). Response to B application was observed in only 20 per cent of the soils containing more than 0.51 mg HWS-B Kg^{-1} thus indicating a 94 per cent predictive value of HWS-B method. Nayyar *et al.* (1985) reported 3.5 mg kg^{-1} DTPA extractable Mn in Ustipsamments and Ustochrepts, whereas for Entisols a critical level of 5.3 mg kg^{-1} DTPA-Mn was found by Gajendragadkar and Rathore (1988) for predicting response of wheat to B deficiency. Shuman *et al.* (1980) reported 0.22 mg kg^{-1} DTPA-Mn level for soybeans grown on a single field. Bansal and Nayyer (1989) reported critical level of 2.9 mg kg^{-1} DTPA-Mn in green gram for soil and 19.0 mg kg^{-1} for plants.

The most commonly used graphical procedure of Cate and Nelson (1965) suffers from human bias in drawing the lines particularly, the one parallel to Y-axis. Additionally, this approach appears subjective since it does not provide adequate test for goodness of fit of data. In order to rectify these errors, the data were subjected to the statistical model of Cate and Nelson (1971) for the determination of critical

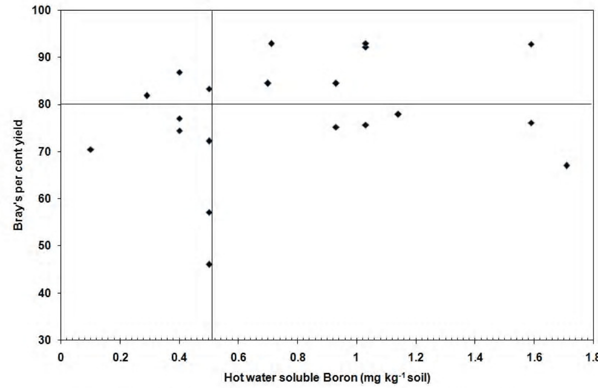

Fig. 1 : Critical limit of boron in soil for toria (*Brasssica compestris*)

Table 1 : Effect of B application on dry matter yield of toria

Soil No.	HWS-B* (mg kg^{-1} soil)	Dry matter yield g pot^{-1} Levels of boron applied (mg kg^{-1} soil) 0	0.22	0.44	0.88	Mean	Bray's % yield
Boron deficient soils (1–9)							
1	0.10	3.17	4.17	4.50	3.72	3.89	70.44
2	0.29	4.52	5.35	5.52	4.51	4.98	81.88
3	0.40	3.99	4.89	4.94	5.36	4.80	74.44
4	0.40	5.23	5.57	6.79	4.4	5.50	77.02
5	0.40	5.50	4.99	6.35	5.25	5.52	86.81
6	0.50	4.92	4.83	5.90	5.42	5.27	83.38
7	0.50	3.69	4.26	8.02	4.12	5.02	46.09
8	0.50	4.01	4.48	7.01	4.36	4.97	57.20
9	0.50	4.94	4.43	6.84	4.67	5.22	72.22
Average of dry matter yield of 1 - 9 soils						5.02	
Boron sufficient soils (10 - 20)							
10	0.70	5.45	5.76	6.45	5.45	5.78	84.49
11	0.71	4.19	4.51	4.31	4.14	4.29	92.90
12	0.93	3.82	3.85	4.52	3.98	4.04	84.51
13	0.93	4.87	4.37	6.47	4.12	4.96	75.27
14	1.03	3.78	3.73	3.99	4.10	3.90	92.19
15	1.03	4.10	4.60	5.42	4.17	4.57	75.64
16	1.03	3.45	3.71	3.45	3.65	3.57	92.99
17	1.14	3.94	3.55	5.12	3.85	4.12	77.92
18	1.59	4.03	4.34	3.84	4.07	4.07	92.85
19	1.59	2.65	2.97	3.48	2.02	2.78	76.15
20	1.71	3.76	4.32	3.89	4.12	4.02	87.04
Average of dry matter yield of 10 - 20 soils						4.19	
Mean of (1-20 soils)	0.80	4.20	4.43	5.30	4.31	4.56	
LSD (0.05)		Dry matter yield for boron levels				0.5	

HWS-B*: Hot water soluble boron

deficiency level of B.

Critical deficiency level of B in plants:

The B concentration in green toria plants (collected at 45 days) grown in control treatment varied from 21.17 to 44.83 mg kg^{-1}. The application of B sharply increased plant B content 1.4 fold on the average with the highest rates of B application (Table 2).The range of B content in plants grown on deficient soils (control) was 27.67 to 44.83 mg kg^{-1} and this increased to 37.50 to 50.33 mg kg^{-1} in B treated pots (Table 4). On B sufficient soil, the B content in the control plants was 21.17 to 42.33 mg kg^{-1} whereas, the B content in the B fertilized plants was 22.33 to 48.00 mg kg^{-1} (Table 2). This suggests that the plants grown on B deficient soils contain less B as compared to those grown in B sufficient soils. According to the Cate and Nelson, (1965, 1971) procedures, the critical level of B in green toria at 45 days below which response to B fertilization could be expected was 29.2 mg kg^{-1} (Fig. 2). This critical level gave a predictability value of 94 per cent. The B content was also significantly related to Bray's per cent yield. Hannam *et al.* (1988) reported 11.0 mg kg^{-1} as the critical level in young emerged leaf blades of 50 dry barley plants. Dhaliwal and Manchanda, (2009) reported a critical limit of 55.00 mg kg^{-1} for moong bean crop on soils with varying B levels. Mascagni and Cox, (1985)

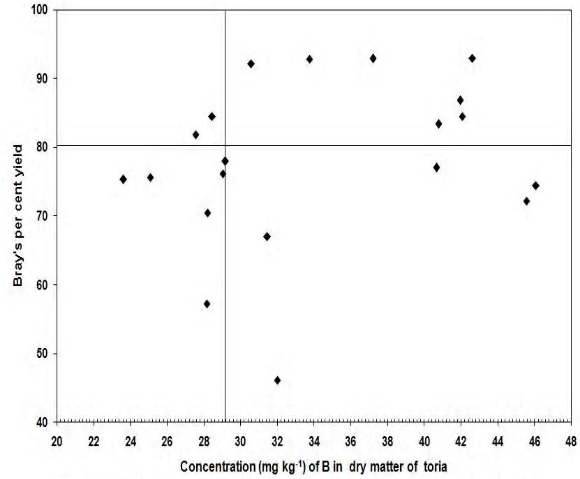

Fig. 2 : Critical limit of boron in plant dry matter of toria (*Brasssica compestris*)

Table 2 : Effect of B application on B concentration of dry matter of toria

Soil No.	HWS-B (mg kg^{-1} soil)	B concentration (mg kg^{-1}) Levels of boron applied (mg kg^{-1} soil) 0	0.22	0.44	0.88	Mean
Boron deficient soils (1 – 9)						
1	0.10	44.67	40.00	49.67	42.50	44.21
2	0.29	40.67	49.83	46.67	48.00	46.29
3	0.40	44.83	47.67	47.00	44.83	46.08
4	0.40	27.67	44.00	48.33	42.67	40.67
5	0.40	42.33	32.50	50.00	43.00	41.96
6	0.50	36.67	40.67	46.17	39.67	40.79
7	0.50	40.00	42.17	45.67	40.17	42.00
8	0.50	41.00	41.00	49.17	37.50	42.17
9	0.50	41.50	46.83	50.33	46.83	45.58
Boron sufficient soils (10 - 20)						
10	0.70	42.33	37.67	43.00	45.33	42.08
11	0.71	36.67	38.00	37.33	36.83	37.21
12	0.93	25.00	30.83	30.50	27.50	28.46
13	0.93	21.17	26.33	22.33	24.67	23.63
14	1.03	27.67	33.67	28.67	32.33	30.58
15	1.03	45.33	44.33	44.33	48.00	45.50
16	1.03	41.33	42.00	41.50	45.67	42.63
17	1.14	28.17	29.17	26.50	32.83	29.17
18	1.59	32.50	33.17	33.67	35.67	33.75
19	1.59	25.50	28.17	27.83	34.67	29.04
20	1.71	28.67	32.17	31.17	33.83	31.46
Mean	0.80	35.68	38.01	39.99	39.13	38.16
	SD (P=0.05)	Boron levels	5.8			

Table 3 : Effect of B application on B uptake by dry matter of toria

Soil No.	HWS-B* (mg kg^{-1} soil)	B uptake (µg pot^{-1}) Levels of boron applied (mg kg^{-1} soil)				Mean	Bray's % uptake
		0	0.22	0.44	0.88		
Boron deficient soils (1-9)							
1	0.10	141.77	166.80	184.51	191.25	171.08	74.13
2	0.29	183.81	266.61	257.60	216.48	231.13	68.94
3	0.40	178.89	233.09	232.18	240.31	221.12	74.44
4	0.40	144.70	245.08	328.18	187.73	226.42	53.28
5	0.40	232.83	162.18	317.50	225.75	234.56	73.33
6	0.50	180.40	196.42	272.38	214.99	216.05	66.23
7	0.50	147.60	179.63	366.25	165.49	214.74	40.30
8	0.50	164.41	183.68	344.66	163.50	214.06	47.29
9	0.50	205.01	207.47	344.28	203.92	240.17	59.55
Boron sufficient soils (10-20)							
10	0.70	239.42	141.25	277.35	235.28	223.33	86.32
11	0.71	153.63	171.38	160.91	152.49	159.60	89.64
12	0.93	89.75	91.58	137.56	90.75	102.41	65.20
13	0.93	111.13	115.08	112.34	96.94	108.87	96.57
14	1.03	104.58	125.58	114.38	132.57	119.28	78.88
15	1.03	145.87	178.66	176.00	178.08	169.65	81.64
16	1.03	142.60	155.82	143.18	166.68	152.07	85.53
17	1.14	110.98	103.54	103.09	126.41	111.00	87.79
18	1.59	130.98	143.94	129.28	145.16	137.34	90.23
19	1.59	88.23	83.66	96.86	70.14	84.72	91.09
20	1.71	94.60	96.18	112.20	97.78	100.19	84.31
Mean	0.80	161.56	162.38	210.53	165.09	174.89	76.73
LSD (0.05)						45	

Table 4: Effect of B application on yield and B content in toria (results are mean values of treatments)

Parameters	Boron status of soil	No. of soils	Rate of applied boron (mg kg^{-1} soil)			
			0	0.22	0.44	0.88
Yeild	Deficient	9	4.44 (3.17-5.50)	4.77 (4.17-5.57)	6.12 (3.72-8.02)	4.73 (4.36-5.42)
(g pot^{-1})	Sufficient	11	4.50 (3.30-10.38)	3.72 (2.97-4.51)	4.23 (3.45-6.45)	3.71 (2.02-5.19)
Boron content	Deficient	9	39.93 (27.67-4.67)	42.74 (32.50-49.83)	48.11 (45.67-50.33)	42.80 (37.50-48.00)
(mg kg^{-1})	Sufficient	11	32.31 (21.17-45.33)	34.14 (26.33-44.33)	33.35 (22.33-44.33)	36.12 (24.67-48.00)

*Deficient soils contain < 0.51 mg kg-1 HWS-B
*Sufficient soils contain >0.51 mg kg-1 HWS-B
**Figures in the parentheses are range values

Table 5 : Effect of B application on yield and concentration parameters

Treatments	Boron levels (kg ha^{-1})				Mean
	0	0.5	1.0	2.0	
B concentration after 45 day (mg kg^{-1})	39.76	40.45	44.84	38.46	40.88
Grain yield at maturity (q ha^{-1})	5.07	5.77	6.33	5.26	5.61
B concentration in grains (mg kg^{-1})	28.83	33.00	37.50	30.67	32.50
B uptake in grains (g ha^{-1})	115.69	132.63	148.83	92.93	122.52
Straw yield at maturity (q ha^{-1})	9.16	9.63	12.12	10.32	10.31
B concentration in straw (mg kg^{-1})	39.33	39.33	43.33	40.17	40.54
B uptake in straw (g ha^{-1})	360.30	378.66	525.08	414.37	419.60

reported 17 to 22 mg kg^{-1} B as the critical level in soybean leaves at early flowering stage. The present study suggested 29.2 mg kg^{-1} B as the critical level in green toria plants at 45 days growth stage. Bansal *et al.* (1987) Reported Mn deficiency on coarser texture soils in barley crop.

Boron uptake by plants increased significantly over control with the graded levels of its application (Table 3). The mean value of B uptake in control of all the 20 soils varied from 88.23 – 232.83 µg pot^{-1} with a mean of 161.56 µg pot^{-1} whereas, the mean values of B uptake in all the B deficient pots varied from 162.18 to 366.25 µg pot^{-1} whereas, the Bray's per cent B uptake by plants in deficient soils varied from 40.30 to 74.44 per cent. On the other hand the mean values of B uptake in all the B sufficient pots varied from 70.14 to 277.35 µg pot^{-1} whereas the Bray's per cent B uptake by plants in sufficient soils varied from 46.9 to 80.8 per cent. The lot of variation in B uptake per pot under among different B treatments was attributed to poor dry matter yield in some pots. Although measurements of the hot water extractable B in the soil can be closely related to B concentrations in leaves and the total uptake of plants especially in pot experiments (Rashid *et al*., 1994), B availability and yield responses to B fertilization in field experiments are additionally influenced by other site conditions which cannot be accounted for by soil analysis. Since the B concentration in old leaves and whole shoots are less reliable in diagnosing the current B status as they reflect past rather than current level of B accumulation, therefore, the recently matured terminal leaves were taken for determining in the critical deficiency level and these results were supported by Bottrill *et al.* (1979) and Malhi *et al.* (2003). Similar observations were reported by Dhaliwal and Manchanda (2009) for mung bean crop

Effect of B fertilizer application in the field experiment:

In the field experiment toria crop showed response to B application and higher response was reported where B was applied at the rate of 1.0 kg ha^{-1}(Table 5). Boron uptake by straw was 10.4 times higher than its corresponding concentration whereas, B uptake by grains was 5.6 times higher than its corresponding concentration. No doubt B application at the rate of 0.5 and 2.0 kg ha^{-1}, too increased the dry matter yield, B concentration and its uptake but comparatively better dry matter yield and its associated parameters were reported with 1.0 kg ha^{-1} B. The dry matter yield of toria increased at both stages of crop growth over control *i.e.* at 45 days old plants and as well as harvesting at maturity (Table 4). The straw yield varied from 9.16 to 10.32 q ha^{-1} with a mean value of 10.31 q ha^{-1}. The mean increase in dry matter yield with application of B fertilizers indicated that the soils are deficient in available B (Table 4). Toria straw was able to retain more B concentration and uptake as compared to its grains and the higher uptake in straw may be attributed to higher biomass of toria at harvesting. The low dry matter yield in control might be due B deficient field which further resulted in poor cell division and elongation in meristematic tissues and floral organs of toria plants. These observations were supported by many research workers. Higher uptake of B in 45 days old moong bean crop was reported by Dhaliwal and Manchanda (2009) on soils with varying B levels. Dell and Huang (1997) reported a direct relationship between biomass yield of wheat leaves and its B uptake. In B deficient plants of spinach, Brown *et al*. (2002) reported that cell elongation was reduced by 32 per cent and dry matter yield by 20 per cent.

Conclusion:

A wide range of soils collected from 20 sites for conducting this investigation, differing in B content (0.10-1.71 mg kg^{-1}) revealed that a critical value of 0.51 mg HWS- B kg^{-1} soil differentiated B responsive soils (9 soils) from the non-responsive soils (11 soils) with toria as a test crop. In the glass house as well as field experiment higher content of B and its uptake was reported with 1.0 kg ha^{-1} B level. All the soils containing 0.51 mg kg^{-1} HWS- B or less than 0.51 responded to B application. The plants grown on such soils contained less B as compared to those grown in B sufficient soils. Further, the results of our investigation suggested a critical level of 29.2 mg B kg^{-1} dry matter at 45 days growth, both the critical levels of B for soil (0.51 mg kg^{-1} soil) and toria plants (29.2 mg kg^{-1}). Similar results were reported with 1.0 kg ha^{-1} B level which confirmed the critical limits of B for soil and toria plants in glass house and under field conditions, respectively. Hence, these research findings could be of great importance for the researchers for investigation and setting up of critical limits of B for other crops in glass house as well as field experiment.

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