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Influence of Boron Application on Root Growth of Green Gram in Loam Textured Soils

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ABSTRACT

Boron (B) is one of the important essential plant micronutrient elements and plays a significant role in physiological and biochemical processes in the legumes and brassica crops. Some of the alkaline calcareous soils are B deficient soils. Root of the crop acts as zone of nutrient absorbing. On its growth and functioning, uptake of any nutrient takes place. A greenhouse experiment with green gram crop was designed to study the effect of B application on root in some alkaline calcareous loam textured soils for two years. Three soils with percent calcium carbonate content 0.75 (S I), 2.1 (S II) and 4.56 (S III) were collected from different sites of Ludhiana and Bhatinda districts, Punjab, India. The treatments comprised of four levels of soil applied B *viz*. 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1} and two levels of foliar applied B *viz*. 0.1 and 0.2 percent borax solution with common control. Soil applied B had more influence on root mean dry matter yield than foliar applied B. Among all soil applied B, 0.5 mg kg^{-1} was best treatment. Soil applied B was more uptake by root as compared to foliar applied B. Among all three calcareous soils, Soil I with lower calcium carbonate was best soil in respect of root mean yield in comparison to Soil III with higher calcareous soils. At grand growth stage, the optimum yield (0.895 mg pot^{-1}) was obtained when root B concentration was 10.6 mg kg^{-1} and the soil applied B level was 0.84 mg kg^{-1} while at maturity stage, the optimum yield (1.28 mg pot^{-1}) was obtained when root B concentration was 10.6 mg kg^{-1} and the soil applied B level was 0.87 mg kg^{-1}.

Key words: Calcareous soils, Dry matter yield of root, Green gram, Root boron concentration, Soil, Foliar applied B.

INTRODUCTION

The role of B is crucial for crop nutrition and thus very essential for yield in terms of seed weight as well as dry matter of shoot and root. The knowledge of relationship between leaf B concentration and yield is well understood. But, about the roots of the crop it is not much clear. Are they contributing some part in growth and development of the crops in terms of nutrient content of the root? Is nutrient uptake by root has something to explain about the physiological and biochemical processes of the crops? As a soil scientist we have to find some relations between root B concentration, dry matter of root and supply of B in different levels.

B deficiency causes major disorder that can limit plant root growth in calcareous soils. Calcareous soils contain calcium carbonate that acts as a sink for B in the soil, where it adsorbs a great portion of the soluble B on the surface of their particles (Goldberg and Forster, 1991). According to Hu and Brown (1997), B uptake is the passive assimilation of undissociated boric acid. B uptake by the root should, therefore, be primarily determined by the B concentration in soil solution and the rate of water uptake by the plant. B uptake by root depends upon many physiological and environmental factors like pH, EC, OC, Clay content, $CaCO_3$ content and many more. Initial B content of the soil also imparts a big role in uptake of B by root.

B uptake by roots of higher plants is passive process acting in response to external fertilizer application (Hu and Brown, 1997). Soil application has more influence on uptake as it adds external B in the soil while no such phenomenon is observed in foliar applied as no translocation of B takes place from upper parts to the underground parts of the crops.

B deficiency in soils inhibits the root growth. B deficiency inhibits root elongation through limiting of cell enlargement and cell division in the growing zone of root tips (Dell and Huang, 1997). Yield and yield attributing characters of crop is directly influenced when deficiency of particular nutrient persist in root of the crop. Similarly, deficiency of B in the root results in poor yield of the crop.

Since, a very few literatures with very scanty information are available related to the effect of B on root of crops. Taking all the information available into account the present study was designed to find out the influence of soil and foliar applied B on root of green gram in some alkaline calcareous soils.

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MATERIALS AND METHODS

Soils with low B and varying $CaCO_3$ content were collected to conduct the greenhouse experiment. The alkaline calcareous soils collected from different locations of Punjab were dried, ground and passed through a 2 mm stainless steel sieve. The physico-chemical characteristics of the processed soils were studied which is given in the Table 1.

Greenhouse studies

Processed soil was taken in polypropylene pots. The B at different levels were applied i.e. 0, 0.5, 0.75, 1.0, 1.5 mg kg^{-1} soil through borax (Soil application). Each treatment was replicated six times. Three replications were harvested at grand growth stage and three replications were left to harvest at maturity. The foliar applications of 0.1% and 0.2% borax solution were applied at grand growth stage in separate pots in which soil applications were not done in three replications prior to the harvest of the crop at grand growth stage. The total numbers of pots were 126. The recommended doses of N and P_2O_5 were added to the soil as urea and KH_2PO_4, respectively. Ten seeds of green gram cv. PAU 911 were sown at field capacity moisture level. After germination, the seedlings were thinned to four plants per pot. The pots were irrigated with deionised water as and when required. The crops were harvested at grand growth stage and at maturity.

The root samples were taken out from underground and processed to make them free from soil particles and other contaminants. The harvested root samples were washed with acidified deionised water, distilled water and then with double distilled water, respectively. The washed root samples were then air dried by keeping them in paper bags and then at oven at 65±2°C. Thereafter, the roots were weighed for dry matter yield and B concentrations were determined.

Laboratory studies

Analysis for B

The B content of the ground roots were determined by dry ashing of the samples according to the method outlined by Gains and Mitchell (1979). In a silica crucible, 0.25 g of the above mentioned dried samples were placed and ashed at 550°C in a muffle furnace. The gray white ash was dissolved in 10 ml of 6 N HCl (distilled HCl) and heated to 80°C on a hot plate to evaporate the content to dryness. The residue was dissolved in deionized water and transferred to 25 ml volumetric flask and volume was made to with deionized water. The solution was then filtered through Whatman No 42 filter paper. The B in the extract was determined by using Azomethine- H as proposed by Gupta (1979).

The statistical analysis of the data was done using a factorial completely randomized design and critical differences (CD) were computed at the 5 percent probability level (Steel and Torrie, 1980). The statistical analysis was carried out with the help of CPCS-1 software and the results so obtained are discussed accordingly.

RESULTS AND DISCUSSION

Dry matter yield of root was observed at both growth stages i.e. at grand growth stage and at maturity. Significant increase in dry matter yield of roots was occurred when B was soil applied at the rate 0.5 mg kg^{-1} soil. Beyond that there was no significant response with increasing levels of soil applied B at both the stages irrespective of type of soils (Table 2). The mean dry matter yield at grand growth stage increased by 24.69, 24.27, 18.03 and 11.79 percent over the control at 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1}, respectively irrespective of soils. Similarly, dry matter yield at maturity increased by 26.03, 24.85, 21.41 and 16.60 percent over

Table 1: Physico-chemical characteristics of soils used for pot culture experiment.

Characteristics	Particle density (g cm^{-3})	Bulk density (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)	Textural class	*pH	*EC (dS m^{-1})	$CaCO_3$ (%)	Available B (mg kg^{-1} soil)	Organic Carbon(%)
Soil I	2.73	1.54	51	32	17	Loam	7.45	0.43	0.75	0.39	0.31
Soil II	2.67	1.56	49	32	19	Loam	7.96	0.61	2.10	0.36	0.45
Soil III	2.63	1.61	42	36	22	Loam	8.08	0.85	4.56	0.29	0.32

Characteristics	Available Macronutrients (mg kg^{-1} soil)			DTPA-extractable micronutrients (mg kg^{-1} soil)				Soil Taxonomy
	N	P	K	Zn	Fe	Mn	Cu	
Soil I	54	11	95	1.06	7.94	7.50	0.82	*Typic Ustochrepts*
Soil II	61	9	130	1.54	4.56	9.40	0.56	*Typic Ustochrepts*
Soil III	49	14	112	1.78	4.72	10.60	0.58	*Ustochreptic Camorthids*

*1:2 Soil: Water suspension (Padbhushan and Kumar, 2015).

the control at these B levels, respectively irrespective of soils. The similar results were recorded by Brown and Hu (1996) in sugar beet and Verma *et al*. (2000) in tomato. For foliar applied B, there was non-significant increase in mean dry matter of root at 0.1 and 0.2 percent borax solution application over control (Table 2).

The mean dry matter yield of root followed non-significant trend as the percent of calcium carbonate content increased in soils irrespective of B. But when we observe the mean value of soils low $CaCO_3$ containing soils have higher dry matter than high $CaCO_3$ containing soils. Combined effect of B application and soils increased dry matter yield significantly up to 0.5 mg B kg^{-1} over control and then remained non-significant with further higher levels of B application. The maximum dry matter recorded at grand growth stage was 0.913, 0.905 and 0.907 g pot^{-1} for Soil I, Soil II and Soil III, respectively. Similarly, the maximum dry matter yield at maturity was 1.324, 1.311 and 1.242 g pot^{-1} for these soils, respectively.

B deficiency was found to severely affect root growth. Dell and Huang (1997) concluded that B deficiency inhibits root elongation through limiting of cell enlargement and cell division in the growing zone of root tips. The similar results were observed by Carpena *et al*. (2000) in pea and Cristobal and Fontes (1999) in tobacco.

Mean B content in root was increased significantly up to 0.5 mg B kg^{-1} of soil applied B over control and then followed non-significantly with further higher levels of B application (Fig 1 and 2). B content in root at grand growth stage increased by 20.31, 24.90, 32.24 and 40.63 percent over control at 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1}, respectively irrespective of soils. Similarly, B content in root at maturity was increased by 21.24, 26.61, 34.41 and 42.20 percent over control at the above mentioned boron level, respectively irrespective of soils. The study showed that when B was added in root medium, its concentration increases linearly in the plant tissue. This may be predicted by more B concentration in the root medium and transpiration rate of the plant (Hu and Brown, 1997). A similar result was observed by Dannel *et al*. (1997and 2000). For foliar applied B, there was non-significant increase in B content at 0.1 and 0.2 percent borax solution application over control.

The mean B content in root was decreased non-significantly for the soils having 0.75, 2.1 and 4.56 percent calcium carbonate levels at both stages of crop growth irrespective of boron levels (Fig 1 and 2). Combined effect of B application and soils B content was increased significantly up to 0.5 mg B kg^{-1} and then behaved non-significantly for soil applied B in all the three soils (Fig 1 and 2). For foliar applied B, there was non-significant increase in B content at 0.1 and 0.2 percent borax solution application over control for all three different soils.

Mean B uptake by root was increased significantly up to 0.5 mg B kg^{-1} of soil applied B over control and then followed non-significantly with further higher levels of B application (Table 3). B uptake by root recorded at grand

Table 2: Effect of B application on dry matter yield of root (g pot^{-1}) at both stages of crop growth in different calcareous soils.

Method of	Treatment	Grand growth				Maturity			
application		Soil I	Soil II	Soil III	Mean	Soil I	Soil II	Soil III	Mean
Soil	B_0	0.73	0.72	0.71	0.72	1.03	1.02	1.00	1.02
(mg B kg^{-1} soil)	$B_{0.5}$	0.91	0.91	0.88	0.90	1.32	1.31	1.21	1.28
	$B_{0.75}$	0.90	0.88	0.91	0.90	1.30	1.27	1.24	1.27
	$B_{1.0}$	0.85	0.84	0.86	0.85	1.25	1.23	1.23	1.24
	$B_{1.5}$	0.80	0.80	0.81	0.81	1.20	1.18	1.18	1.19
Foliar	$B_{0.1}$	0.73	0.72	0.71	0.72	1.07	1.10	1.06	1.08
(% Borax solution)	$B_{0.2}$	0.73	0.73	0.72	0.72	1.08	1.10	1.07	1.09
Mean		0.81	0.80	0.80		1.18	1.17	1.14	
	Boron level:			0.05			0.07		
LSD (0.05)	Soil level:			NS			NS		
	Interaction:			0.08			0.11		

Table 3: Effect of B application on boron uptake by root (µg pot^{-1}) at both stages of crop growth in different calcareous soils.

Method of	Treatment	Grand growth				Maturity			
application		Soil I	Soil II	Soil III	Mean	Soil I	Soil II	Soil III	Mean
Soil	B_0	5.68	5.51	5.31	5.50	7.77	7.59	7.40	7.59
(mg B kg^{-1} soil)	$B_{0.5}$	8.48	8.35	7.92	8.25	12.05	11.92	10.75	11.57
	$B_{0.75}$	8.60	8.40	8.62	8.54	12.27	11.97	11.68	11.97
	$B_{1.0}$	8.65	8.48	8.64	8.59	12.64	12.29	12.14	12.35
	$B_{1.5}$	8.73	8.53	8.68	8.65	12.91	12.47	12.27	12.55
Foliar	$B_{0.1}$	5.76	5.58	5.42	5.58	8.22	8.26	7.90	8.13
(% Borax solution)	$B_{0.2}$	5.79	5.61	5.52	5.64	8.43	8.33	8.30	8.35
Mean		7.38	7.21	7.16		10.61	10.40	10.06	
	Boron level:			0.64			0.85		
LSD (0.05)	Soil level:			NS			NS		
	Interaction:			1.11			1.48		

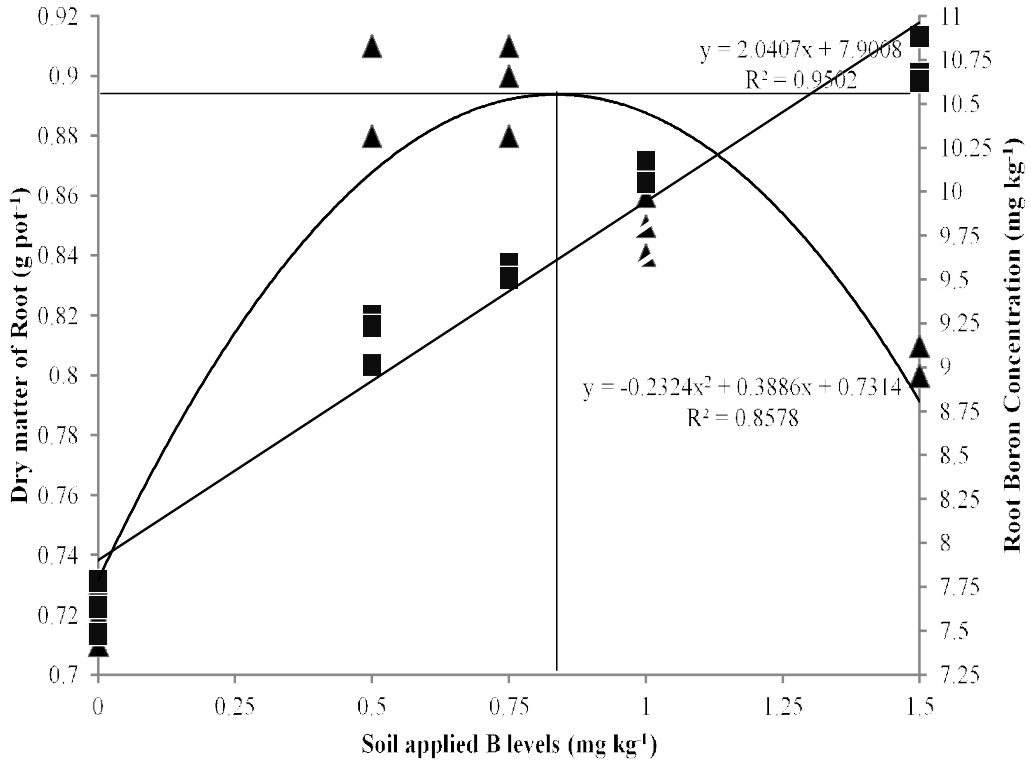


Fig 1: Dry matter of Root Vs Soil applied B levels Vs Root Boron Concentration at grand growth Stage in different calcareous soils.

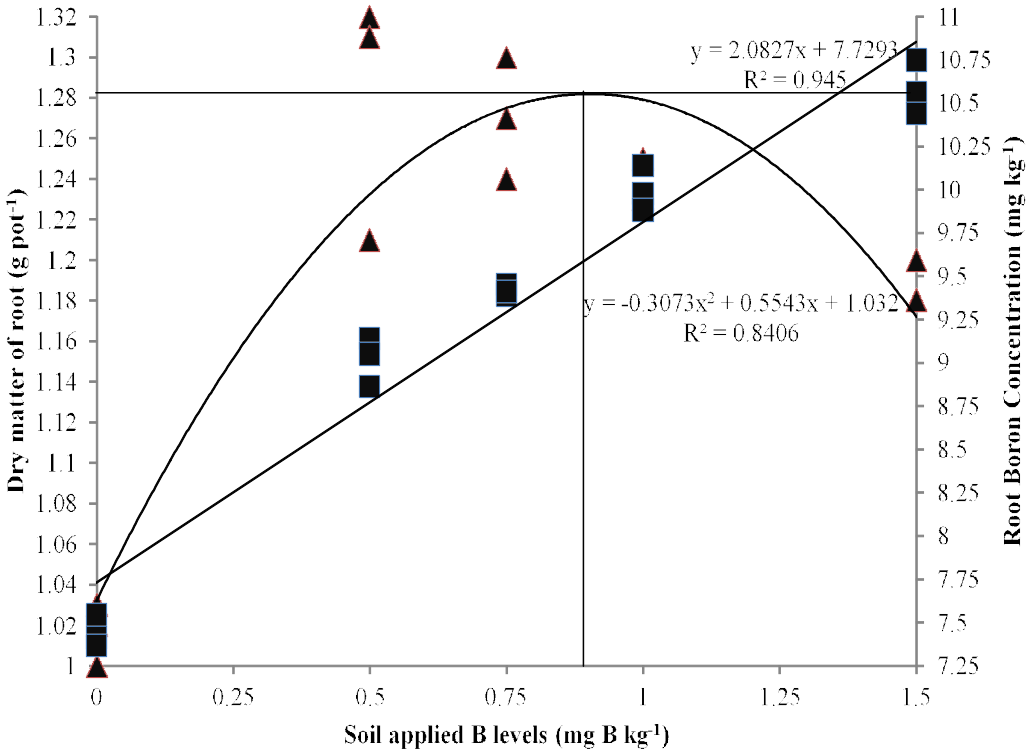


Fig 2: Dry matter of Root Vs Soil applied B levels Vs Root Boron Concentration at maturity Stage in different calcareous soils.

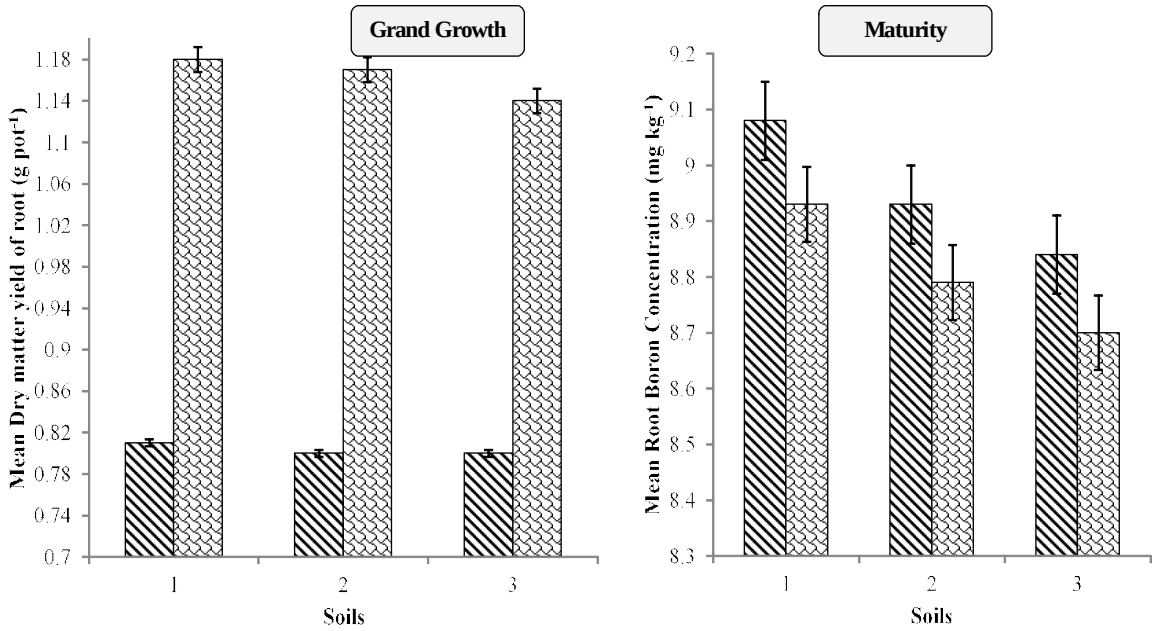


Fig 3: Represents mean dry matter of root and mean root boron concentration in different alkaline calcareous soils at the both stages of crop growth.

growth stage was increased by 50.00, 55.27, 56.18 and 57.27 percent over control at 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1} soil, respectively irrespective of soils. Similarly, B uptake by root at maturity was increased by 52.44, 57.71, 62.71 and 65.35 percent over control at 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1} soil, respectively irrespective of soils (Table 3).

For foliar applied B, there was non-significant increase in B uptake by root at 0.1 and 0.2 percent borax solution application over control. Different soils irrespective of B levels were not effective in influencing the mean B uptake by root at both stages of crop growth. The mean B uptake by root decreased non-significantly for soils having 0.75, 2.1 and 4.56 percent calcium carbonate levels. Combined effect of B application and soils was increased B uptake significantly up to 0.5 mg B kg^{-1} over control in all the three soils and then followed non-significantly B for different soil applied B levels (Table 3). For foliar applied B, there was non-significant trend in B uptake at 0.1 and 0.2 percent borax solution application over control for all three different soils. Different soils irrespective of B levels were not effective in influencing the mean B uptake by root at both stages of crop growth. B uptake is the result of the passive assimilation of undissociated boric acid as it is membrane permeable. B uptake primarily determined by the B concentration in the soil solution and the rate of water uptake by the plant (Hu and Brown, 1997).

Dry matter of root vs soil applied B levels vs root B concentration at different stages of crop growth and different calcareous soils

Fig 1 and 2 represents the relationship between dry matters of root Vs soil applied B levels Vs root B concentration at grand growth stage and maturity stage in some alkaline calcareous soils. At grand growth stage, the optimum yield (0.895 mg pot^{-1}) was obtained when root B concentration was 10.6 mg kg^{-1} and the soil applied B level was 0.84 mg kg^{-1} while at maturity stage, the optimum yield (1.28 mg pot^{-1}) was obtained when root B concentration was 10.6 mg kg^{-1} and the soil applied B level was 0.87 mg kg^{-1}. The figure showed that these parameters are highly correlated with one another. Dry matter of root is highly correlated with soil applied B levels at both stages of crop growth. Root Boron concentration got increased on application of B in the soils.

Fig 3 represents the mean dry matter of root and mean root boron concentration in different alkaline calcareous soils at the both stages of crop growth. This figure showed the effect of B on the different stages of crop growth. The mean dry matter of root got increased at maturity with respect to grand growth stage while mean root boron concentration got decreased due to movement of boron from underground to aerial parts of the crop.

CONCLUSION

Root growth has direct influence on supply of boron in soil. Due to adsorption of B by the root, physiological and biochemical activities of root gets increased resulting in more mean dry matter of root. Root B concentration decreases from grand growth stage to maturity due to movement of B from underground to aerial parts take place continuously.

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