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Response of soybean (Glycine max L.) to levels of boron in a Vertisol

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ABSTRACT

Field experiment was conducted at JNKVV research farm during Kharif season of 2012-13 to evaluate the response of soybean (var. JS 97-52) under different boron levels (0, 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1}). The soil of the experimental site was Typic Haplusterts having pH 7.5, E.C. 0.20 dSm^{-1}, organic carbon 4.92 g kg^{-1} and marginally low boron content. The results reflected a significant superiority of boron application on yield of soybean as compared to control. Highest seed yield (2.76 t ha^{-1}) of soybean was recorded with 1.5 kg B ha^{-1} and proved significantly superior over control. Boron levels significantly increased the boron content in plant over control and maximum B content in plant at 30, 45 and 60 DAS (28.84, 38.17, 51.51 mg kg^{-1}) and at harvest in seed and stover (41.68 and 38.35 mg kg^{-1}) was obtained under the treatment of 2.0 kg B application ha^{-1}, respectively. B uptake in seed (111.8 g ha^{-1}) and stover (105.8 g ha^{-1}) was found maximum in 2.0 kg B ha^{-1} and 1.5 kg B ha^{-1}, respectively. Available boron buildup in soil was obtained due to different levels of boron application with highest (0.723 mg kg^{-1}) in of 2.0 kg B ha^{-1} treatment and changes in soil boron content among different treatments was statistically significant. Quadratic relationships were obtained between boron levels and boron uptake (R^2=0.97), physiological efficiency (R^2=0.95), agronomic recovery efficiency (R^2=0.83) and boron use efficiency (R^2=0.84).

Key words: Soybean, boron levels, yield, boron content, boron uptake, correlation.

INTRODUCTION

Soybean is one of the most important oilseed crops of India occupies about 10.97 M ha and annual production of 11.49 million tones with a mean productivity of 1047 kg ha^{-1}. Madhya Pradesh is the largest soybean producer and known as "Soya State" in the country, where area occupied is 5.40 million ha and average annual production 5.72 million tones with an average productivity of 1058 kg ha^{-1} (SOPA, 2016) contributing about 50% production from 49% of soybean grown area of the country. The use of micronutrients in soybean is one of the ways to boost up the productivity and to improve quality parameters of seed. Improper use of chemical fertilizers has caused nutritional imbalance in the soil, instability in productivity and hidden hunger, besides depletion of nutritional quality of the pulses (Bairwa *et al.*, 2009; Bhattacharjee *et al.*, 2011). In addition, due to intensive cultivation of soybean based cropping systems in Vertisol of Madhya Pradesh using high analysis fertilizers (micronutrient free) has resulted in accelerated depletion in essential plant nutrients from soil, especially micronutrients. Boron is one of the most essential micronutrients and directly involved in several physiological and bio-chemical processes during plant growth (Sinha and Chatterjee, 2003). Key roles of B include sugar transport, cell wall synthesis, lignifications, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid metabolism, phenol metabolism, and as part of the cell membranes. Boron also maintains the membrane integrity and cell wall development, which affects permeability, cell-division and its extension. More over to this, boron is essential for pollen tube growth in soybean crop. World-wide, boron deficiency is more extensive than any other plant micronutrient. Total B in Indian soils has been found to vary from 7 to 630 mg kg^{-1}. Boron deficiency is the second most widespread micronutrient problem globally (Alloway, 2008). Keeping these in view, present study was under taken to evaluate the effect of different levels of boron application on soybean productivity and B content in plants and soil.

MATERIALS AND METHODS

Field experiment was conducted during *Kharif* season of 2012 at the research farm of J.N. Krishi Vishwa Vidyalaya, Jabalpur (23^0 13'

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N lat., 79^0 57’ E long. and elevation of 393.0 m. amsl.). The soil of the experimental field was Vertisols belonging to fine montmorillonite, Hypothermic family of *Typic Haplusterts,* also known as “Black cotton soil” having pH (7.5), EC (0.10 dSm^{-1} at 25 ^{0}C), organic carbon (4.92 g kg^{-1}) and available boron (0.468 mg kg^{-1}). The experiment was laid out in randomized block design with five treatments of boron levels (0, 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1}) along with recommended dose of major nutrients (N:P_2O_5 : K_2O as 20:80:20 kg ha^{-1}) and the treatments were replicated four times in 04 m x 04 m plot size. Nitrogen, phosphorous, potassium and boron were applied through urea, single super phosphate, muriate of potash and borax (10.6% B), respectively in soil at the time of sowing. Sowing of seeds was done on 13-07-2012 and crop harvested on 05-11-2012. Standard procedure was followed for analysis of boron in soil and plant (Berger and Troug, 1939). Boron uptake (BU), physiological efficiency (PE), apparent recovery efficiency (ARE) and boron use efficiency (BUE) were computed by following equations. BU (g ha^{-1}) = B content (mg kg^{-1}) * yield (kg ha^{-1}) /1000,

i. PE (kg g^{-1}) = (DMx - DMy) / (BUx - BUy)
ii. ARE (%) = [(BUx – BUy) / Boron applied (kg ha^{-1})]*1000
iii. BUE (kg g^{-1}) = PE * ARE
iv.

Where: DM- dry matter (kg ha^{-1}), x-fertilized plot and y - unfertilized plot

Statistical analysis of the data was done using critical difference procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield and boron uptake

The data (Table 1) reveal that maximum seed and stover yield (2.76 t ha^{-1} and 2.91 t ha^{-1}) was recorded with 1.5 kg B ha^{-1} followed by (2.75 t ha^{-1} and 2.88 t ha^{-1}) 1.0 kg B ha^{-1} and minimum seed and stover yields (2.45 t ha^{-1} and 2.37 t ha^{-1}) were produced under control. Also the yield in the treatment received 1.5 and 1.0 kg B ha^{-1} were significantly superior over control. Whereas, seed yield in the treatments of 0.5 and 2.0 kg B ha^{-1} application were on par with control. It might be because of optimal growth conditions were obtained under application of 1.5 kg B ha^{-1} treatment. Similar findings were also reported by Singh *et al.* (2002) and Choudhary and Bhogal (2017) which showed that application of 1.5 kg B ha^{-1} as borax gave higher yield in different crops during kharif as well as rabi seasons. Data (Table 1) further showed that increasing level of boron (0.0, 0.5, 1.0, 1.5, 2.0 kg ha^{-1}) significantly increased the total boron uptake by soybean. Maximum boron uptake (214.9 g ha^{-1}) was obtained at highest level of B (2.0 kg B ha^{-1}) and minimum (127.7 g ha^{-1}) in control. Among the treatments boron uptake under control and 0.5 kg B ha^{-1} was significantly lower as compared to 1.0, 1.5 and 2.0 kg B ha^{-1} which were statistically at par among themselves. Greater uptake of boron in higher levels of its application may be attributed to higher concentration and enhanced yield of soybean. Similar results were also reported by Singh *et al.* (2017) Kumar and Sidhu (2010) which indicate that boron uptake was maximum with 2.0 kg B ha^{-1}.

Table 1: Effect of levels of boron application in soybean on yield, boron uptake and available boron in soil

Boron (kg ha^{-1})	Soybean yield (t ha^{-1})		Total B uptake (g ha^{-1})	Post harvest Available soil boron (mg kg^{-1})
	Seed	Stover		
0.0	2.45	2.37	127.7	0.464
0.5	2.68	2.65	151.4	0.560
1.0	2.75	2.88	198.4	0.608
1.5	2.76	2.91	212.1	0.665
2.0	2.68	2.70	214.9	0.723
S Em ±	0.09	0.16	6.92	0.015
CD *(p = 0.05)*	0.27	0.47	20.35	0.043

Data (Table 1) also showed that increasing level of boron (0.0, 0.5, 1.0, 1.5, 2.0 kg ha^{-1}) significantly increased the boron content in post harvest soil. Maximum buildup of boron

(0.723 mg kg^{-1}) in soil was found in 2.0 kg B ha^{-1} followed by 0.665 and 0.608 mg kg^{-1}, respectively in 1.5 and 1.0 kg B ha^{-1}. Depletion in soil boron (0.464 mg kg^{-1}) from its initial value (0.468 mg kg^{-1}) was found in control. Results clearly revealed a significant buildup of boron in soil due to increasing level of boron application. It may be because of more supply of boron in soil as compare to its demand to crop. (Ali, 2017) also reported similar findings which indicate that boron content in soil increased with increasing boron application in soil.

Boron content

Increasing levels of boron amplified the B content in soybean plants at 30, 45 and 60 DAS and highest values were found in 2.0 kg B ha^{-1}, while lowest values obtained in control (Table2). At 30, 45 and 60 DAS, maximum B content in plants were 28.84, 38.17 and 51.51 mg kg^{-1}, respectively in 2.0 kg B ha^{-1} treatment. Boron content in plants at 30, 45 and 60 DAS was significantly superior in 1.0, 1.5 and 2.0 kg B ha^{-1} treatments as compared to 0.5 kg B ha^{-1} and control as well, but B contents in plants under 1.0, 1.5 and 2.0 kg B ha^{-1} treatments were statistically at par. Increasing concentration of boron in plants with increment in its levels might be due to easily available boron content in soil under higher dose of boron applied. (Singh *et al.* (2017) also reported that maximum boron content in soybean plant at higher dose of application. Boron content in seed and stover varied from 27.93 to 41.68 mg kg^{-1} and 25.51 to 38.35 mg kg^{-1}, respectively with highest boron level (2.0 kg B ha^{-1}) and lowest in control (27.93 mg kg^{-1} and 25.51 mg kg^{-1}). B content in seed with 1.0, 1.5 and 2.0 kg B ha^{-1} was significantly superior over control and 0.5 kg B ha^{-1}, but there was no significant difference in B content under different levels of boron. The values of B content in stover with 1.0, 1.5 and 2.0 kg B ha^{-1} were at par among themselves though these boron levels were significantly superior to 0.5 kg B ha^{-1} and control. The increase in boron concentration in grain and straw might be due to easily available boron content in soil under higher dose of boron applied.

Table 2: Effect of boron levels on boron content in soybean

Boron (kg ha^{-1})	Boron content in soybean (mg kg^{-1})				
	30 DAS	45 DAS	60 DAS	At harvest	
				Seed	Stover
0.0	23.05	26.62	41.42	27.93	25.51
0.5	24.16	28.92	45.31	30.09	26.72
1.0	28.15	33.73	49.07	36.77	33.42
1.5	28.25	36.50	49.56	38.66	36.00
2.0	28.84	38.17	51.51	41.68	38.35
SEm $\pm$	1.19	1.52	2.35	2.09	1.69
CD (*p=0.05*)	3.52	4.48	6.91	6.16	4.99

Efficiency indices

Efficiency indices (physiological use efficiency, apparent recovery efficiency and boron use efficiency) of soybean were also worked out (Table 3) which indicates that with increasing level of boron physiological efficiency decreased from 18.88 to 6.17 kg g^{-1}. It was also found that apparent recovery efficiency (9.34 %) and boron use efficiency (107.82 kgg^{-1}) increased up to 1.0 kg B ha^{-1} and then decreased with increasing level of boron (2.0 kg Bha^{-1}).

Table 3: Effect of boron levels on boron efficiency indices

Boron (kg ha^{-1})	Physiological efficiency (kg g^{-1})	Apparent recovery efficiency (%)	Boron use efficiency (kg g^{-1})
0.5	18.88	4.61	87.00
1.0	11.54	9.34	107.82
1.5	10.48	2.84	29.77
2.0	6.17	0.56	3.43

Correlation and regression study

Relationship between applied boron and boron uptake, physiological use efficiency, apparent recovery efficiency and boron use efficiency of soybean was studied and quadratic relationships were obtained which are given as below:

i. Boron uptake in grain (g ha^{-1}) = $-2.29*X^2 + 25.01*X + 43.88$ (R^2=0.98)
ii. Boron uptake in stover (g ha^{-1}) = $-3.07*X^2 + 30.64*X + 28.99$ (R^2=0.98)
iii. Physiological efficiency (kg g^{-1}) = $3.03*X^2 – 15.4*X + 25.35$ (R^2=0.95)
iv. Apparent recovery efficiency (%) = $-3.63*X^2 + 8.63*X + 1.39$ (R^2=0.83)
v. Boron use efficiency (kg g^{-1}) = $-47.15*X^2 +52.13*X + 80.25$ (R^2=0.84)

Where: X is level of boron application (kg ha^{-1})

It was found that quadratic equations obtained for boron uptake in seed and stover of soybean, physiological efficiency of boron (amount of biological yield per unit boron uptake), apparent recovery efficiency and boron use efficiency in relation to level of boron application had high predictability to the extent of 98.0, 98.0, 95.0, 83.0 and 84.0 per cent, respectively. It could be because of difference between nutrient demand and supply mechanisms of plant. The findings are well supported with those reported by Singh *et al.* (2012).

Present study concluded that for higher yield of soybean grown in a Vertisol, application of 1.5 kg B ha^{-1} was found optimal. It was also concluded that increasing levels of boron application enhanced the boron content and uptake in soybean plants at temporal level and also in seed and stover. Boron uptake in seed and stover of soybean, physiological efficiency of boron, apparent recovery efficiency and boron use efficiency were highly correlated with levels of boron application in soybean.

REFERENCES

Ali, J. (2017) Effect of boron, zinc and sulphur on soil fertility and yield of fababean (*Vicia faba* L). *Annals of Plant and Soil Research* **19** (3): 329-333

Alloway, B.J. (2008). (ed). Micronutrient deficiencies in global crop production. Springer science+ Business Media B.V, Netherland.

Bairwa HL, Mahawer LN, Shukla AK, Kaushik RA and Sudha Mathur R. (2009) Response of integrated nutrient management on growth, yield and quality of okra (*Abelmoschus esculentus*). Indian Journal of Agriculture Sciences **79**(5): 381-403.

Berger, K.C. and Truog, E. (1939) Boron determination in soils and plants. Ind.Eng.Chem.Anal.Ed.11:540-545.

Choudhary, S. and Bhogal, N.S. (2017) Effect of boron on yield, quality and its uptake in India mustard (*Brassica juncea*) genotypes. *Annals of Plant and Soil Research* **19** (4): 394-397

Bhattacharjee S, Singh AK, Singh AP and Singh AK. (2011) Effect of phosphorus, sulphur and cobalt on growth, yield and nutrient content of soybean and soil fertility. Bangladesh Journal of Agriculture and Environment **7**(1): 25-29.

Gomez, A.A. and Gomez, K.A. (1984) Statistical procedures for Agricultural Research. 2nd Edn. John Wiley and Sons, New York.

Kumar, Dinesh and Sidhu, Sudeep (2010) Effect of soil applied sulfur and boron on yield and uptake of boron in soybean. Annals of Agri Bio Research. **15** (1): 57-62.

Singh, Room, Yadav, D.S. and Maurya, M.L. (2002) Effect of boron application on yield of pea (Pisum sativum L.) and black gram (Vigna mungo Hepper) in calcareous soil. Fertiliser News. 47 (2): 67-68.

Singh, R., Komar, Y. and Singh, S. (2017) Yield, quality and nutrient uptake of mustard (*Brassica juncea*) under sulphur and boron nutrition. *Annals of Plant and Soil Research* **19** (2): 227-231

Singh, Shailendra , Chopra, Shailendra, Reddy, K. S. and Leelavati (2012) Influence of sulphur and boron on yield attributes and yield of soybean. Crop Research (Hisar) **44** (3): 318-321.

Sinha, Pratima and Chatterjee, C. (2003) Influence of low boron on yield and seed quality of soybean. Indian Journal of Agriculture Research **37**(3): 193-198.

SOPA (The Soybean Processors association of India) 2016.www.sopa.org.