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Relative changes in total available boron, boron content at different growth stages and total boron uptake by black gram under different sources and doses of boron

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Abstract
A field experiment was conducted to investigate the "Relative changes in Boron fractions in black gram Rhizosphere" was contemplated with two objectives: 1) To find out the suitable source, dose and method of boron for black gram, and 2) To study the changes in relative boron fractionation under black gram Rhizosphere. To achieve the present objectives a field experiment was conducted with Greek gram var. IPU2-43 in factorial randomized block design with three sources, four doses and two methods of application of boron replicated thrice at Bihar Agricultural College Farm of BAU, Sabour during the year 2018-19. Three sources were: S_1: Borax, S_2: Solubor and S_3: Boric acid; Doses: D_1: 0.5 kg ha^{-1}, D_2: 1.0 kg ha^{-1}, D_3: 1.5 kg ha^{-1}, D_4: 2.0 kg ha^{-1}and methods: soil and foliar application. Based on the findings of field experiment it can be concluded that the application of graded doses of boron enhanced the growth and yield as well as concentration and uptake of boron. The result showed that highest value (101.62 mg/kg of soil) of total available boron was recorded under $D_4S_1$and lowest value (96. 38 mg/kg of soil) was recorded under D_1S_2. The highest boron content at the vegetative stage in plant was found in the solubor applied plots (8.96 mg kg^{-1}) which were significantly superior over boric acid and borax treated plots. Among the plots receiving various different doses of boron, the highest boron content was observed at 2.0 Kg B ha^{-1} (8.49 mg kg^{-1}) which was significantly superior to the plots under D_1 and D_2 and at par with plots receiving 1.5 Kg B ha^{-1} (8.18 mg kg^{-1}). At the flowering stage in plant higher boron content was found in solubor (10.16 mg kg^{-1}) applied through foliar application which significantly varied from the rest of the two sources. The content recorded under the other two sources was found to be statistically at par. Regarding the application of different doses of boron the highest boron content was found at 2.0 kg B ha^{-1} (10.02 mg kg^{-1}) which statistically at par with that at 1.5 kg B ha^{-1} (9.90 mg kg^{-1}). Foliar application of solubor recorded highest value (14.13 mg kg^{-1}) of boron content in grain. Boron content in the grain at harvesting. However, among the plots receiving different doses of boron it was found that the boron content in seed in the plots receiving 2.0 Kg B ha^{-1} (14.25 mg kg^{-1}) was significantly higher than other three plots. Regarding the boron content in the straw at harvest it was found the highest boron content in straw was recorded under plots which received Solubor through foliar application (17.09 mg kg^{-1}).Total uptake at 1.5 kg B ha^{-1} was at par with 2.0 kg B ha^{-1} but significantly superior over the rest of the lower doses.

Keywords: Total available boron, flowering stage, vegetative stage, total boron content

Introduction
Boron management is challenging because the optimum B application range is narrow and optimum B application rates can differ from one soil to another. Among micronutrients, B deficiency is wide spread throughout India. Factor such as pH, texture, organic matter, temperature, moisture content and plant species influence B adsorption, and thereby, plant B uptake. Coarse textured soils prone to leaching as a result of excessive rainfall in humid climate are generally associated with B deficiency. Boron is retained in soils by adsorption onto minerals and humic particles and by forming insoluble Total boron content in Indian soils has been reported to varying from 3.80 to 630 mg kg^{-1} and available boron from 0.04 to 7.40 mg kg^{-1}.Black gram (*Vigna mungo*L.) is an important pulse crop of the tropic and sub-tropic area and has been identified as a potential crop in many countries. Black gram commonly known as urd bean or mash. It is one of the important grain legumes and is an excellent source of easily digestible good quality protein (Srivastava *et al*. 2011) [21]. In India black gram is shown in the area of 50.31 lakh ha with 32.84 lakh ton production and the productivity of 651 kg ha^{-1} (Ministry of Agriculture and Farmers Welfare (Department of Agriculture, Cooperation & Farmers Welfare 2017-18) and in the Bihar the area under cultivation is 15.5 ('000) ha and

productivity is 912 kg ha^{-1} (Singh *et al*. 2016)[19]. At present about 33 % area at national level and 38 % area in Bihar are B deficient (Singh, 2001) [20]. Boron is an essential micronutrient required for growth and development of vascular plants, diatoms and species of marine algal flagellates. Leguminous plants as well as cyanobacteria require B for N_2 fixation, as B plays a major role in nitrogen assimilation (Brown and Shelp, 1997) [3]. Boron (B), an essential micronutrient, plays an important role in cell wall structure, membrane stability, sugar transportation and phenol, carbohydrate, nucleic acid and IAA (Indol acetic acid) metabolism. In addition to its involvement in numerous metabolic processes, B has a great impact on productive structure development especially on microsporogenesis, pollen germination and seed development (Pandey and Gupta, 2013) [16]. Boron management is challenging because the optimum B application range is narrow and optimum B application rates can differ from one soil to another (Gupta, 1993; Marschner, 1995) [7, 12]. The boron content in the soil changes between 2 and 100 ppm (Swaine, 1955) [22]. Average boron is considered 30 ppm in soil depending on the main rock; boron content in the soil exhibits a large variation. Consequently, plants need trace amounts of boron but it becomes toxic at 2 ppm or greater for most plants (Carlos, 2000) [4]. A tolerable boron concentration for plants in soils is approximately 25 ppm (Khan 2009) [11]. Generally speaking, there is more boron in the subsoil and deeper (Haas, 1992) [8]. Among micronutrients, B deficiency is wide spread throughout India. Reasons behind the boron deficiency are - High soil pH, coarse texture, low organic matter and low moisture content (Pandey and Gupta, 2013) [16]. Boron is very important in cell division, pod and seed formation. Factor such as pH, texture, organic matter, tempeture, moisture content and plant species influence B adsorption, and thereby, plant B uptake. Coarse textured soils prone to leaching as a result of excessive rainfall in humid climate are generally associated with B deficiency (Goldberg, 1997) [6]. Roots of many crops (Such as pulses and oilseeds) may beyond the surface layer to derive part of their nutrient requirements from the subsurface layer, therefore it is desirable to have information about the depth wise distribution of available Boron content in the soil. Being a less mobile nutrient in plants, boron deficiency symptoms first appear on stem tips, young leaves, flowers and buds (Dobermann and Fairhurst, 2000) [5]. B deficiency symptoms in plants include dark green, leathery, downward cupping of leaves and dieback of shoot tips (Bell, 1997) [1]. Boron is retained in soils by adsorption onto minerals and humic particles and by forming insoluble precipitates (Goldberg and Glaubig, 1985). Total boron content in Indian soils has been reported to varying from 3.80 to 630 mg kg^{-1} and available boron from 0.04 to 7.40 mg kg^{-1} (Takkar and Randhawa, 1978) [23].

Methods of analysis

Soil sample were collected from BAC, Sabour, Farm. Collected soil was completely air dried in shade powdered in wooden mortar with pestle and sieved through 2 mm sieve for further analysis. The Boron from the soil was extracted from soil with water (1:2) by refluxing for 5 minutes on Hot Plate-Unitech (Berger and Troug 1939) [2]. The HWEB in the extractant was determined by spectrophotometer at 420 nm using Azomethine-H as indicator (John *et al.* 1975) [10].

Total boron content in plant samples were determined as per the method outlined by (Jackson, 1973) [9]. 1 gm dry powdered plant samples were weighed in silica crucible and placed in muffle furnace for 1-3 hrs at 450-600 ºC and then cooled. The sample color was grayish or white. Then samples were wetted with 8-10 drops of deionized water and subsequently with 20 ml 0.1N HCl with the help of a pipette into the crucible. Samples were then kept or reaction at room temperature for just about 50 to 60 minutes. Sporadically samples were stirred with the help of plastic or boron free glass rod to break up ash. Then these samples were filtered through Whatman no. 1 filter paper. This filtrate was used for B determination.

Colour was developed by pipetting 2 ml sample filtrate into test tube and added to it 2 ml of buffer-masking reagent and 1 ml Azomethine-H reagent. Samples were mixed up meticulously and thoroughly. Then samples were allowed to develop colour for 1 hr. After colour development these samples were measured for their absorbance at 420 nm using a Spectrophotometer. Boron concentrations of sample were determined from the standard curve constructed by plotting absorbance versus concentration of standards in µg B/ml. (John *et al.* 1975) [10].

Results and Discussion

Total Boron (T- B)

The perusal data on Total Boron (T- B) in soil illustrated in Table- 1 revealed that Total Boron (T- B)content of the soil ranged between 96.38 to 101.62 mg kg^{-1} of soil. The highest value was recorded under D_4S_1 and lowest under D_1S_2. The T-B content of the soil was found higher under the plots receiving higher doses of boron irrespective of sources and methods of application. However, it was found that the sources, doses as well as their interactions had no any significant effect on the T-B content of soil. Total B content in the soil depends upon physico-chemical conditions of the soil. Mean total B content increased non-significantly with increase in rate of B application The T-B content of a soil is not a reliable indicator of available B. Similar kind of work was reported by the Padbhushan and Kumar(2015) [15].

Table 1: Effect of different sources of Boron and its different doses on Total Boron (T- B) (mg kg^{-1}) of the soil

Sources / Doses	S_1 Borax Soil application	S_2 Solubor Foliar application	S_3 Boric acid Soil application	Mean
D_1 0.5 kg ha^{-1}	99.01	96.38	99.21	98.20
D_2 1.0 kg ha^{-1}	99.24	98.00	99.79	99.01
D_3 1.5 kg ha^{-1}	99.96	100.52	100.75	100.41
D_4 2.0 kg ha^{-1}	101.62	100.76	99.04	100.47
Mean	99.96	98.92	99.70	

Sources	SEm (±)	C.D (P=0.05)
S	2.07	NS
D	2.40	NS
S×D	4.15	NS

Boron content at different stages of crop

The data with respect to boron content at three different stages of crop i.e vegetative (30 DAS), flowering (60 DAS) and at harvest is presented in Table -2 The boron content at the vegetative stage in plant was significantly affected due to the use of various sources of boron. The highest boron content was found in the solubor applied plots (8.96 mg kg^{-1}) which were significantly superior over boric acid and borax treated plots. The boron content in the black gram with plots treated with borax (S_1) too differed significantly with the plots where Boric acid was applied (S_3).Among the plots receiving various different doses of boron, the highest boron content was observed at 2.0 Kg B ha^{-1} (8.49 mg kg^{-1}) which was significantly superior to the plots under D_1 and D_2 and at par with plots receiving 1.5 Kg B ha^{-1} (8.18 mg kg^{-1}). This might be due to the application of increasing dose of boron fertilizer which was easily available to the plant. Solubor showed the highest boron content because it was applied in foliar application. This result is supported by the Mevada *et al*. (2005) [13] and Sharma *et al*. (2005) [18]

The perusal of data with respect to boron content at the flowering stage (60 DAS)in the plant tabulated in Table -2 showed that boron content at the flowering stage in plant was significantly affected due to the use of various sources, doses as well as methods of application of boron. Higher boron content was found in solubor (10.16 mg kg^{-1}) applied through foliar application which significantly varied from the rest of the two sources. The content recorded under the other two sources was found to be statistically at par. Regarding the application of different doses of boron the highest boron content was found at 2.0 kg B ha^{-1} (10.02 mg kg^{-1}) which statistically at par with that at 1.5 kg B ha^{-1} (9.90 mg kg^{-1}). This might be due to the consumption of micro nutrient is high for the better metabolic process of the plant. The result is supported by the Mevada *et al.* (2005) [13] and Sharma *et al*. (2005) [18].

Table 2: Boron content in plant of black gram at different stages as influenced by different treatments

Treatments	B content in plant (mg kg^{-1})			
	30 DAS	60 DAS	At Harvest	
			Grain	Straw
Sources of boron				
S1- Borax	7.49	9.81	13.64	16.60
S2- Solubor	8.96	10.16	14.13	17.09
S3- Boric acid	8.01	9.84	13.81	16.78
SEm±	0.12	0.08	0.14	0.15
CD (P=0.05)	0.35	0.25	NS	NS
Doses of Boron (kg B ha^{-1})				
D_1 - 0.5 kg B ha^{-1}	7.92	9.62	13.49	16.46
D_2- 1.0 kg B ha^{-1}	8.03	9.76	13.82	16.79
D_3- 1.5 kg B ha^{-1}	8.18	9.90	13.87	16.83
D_4 –2.0 kg B ha^{-1}	8.49	10.02	14.25	17.22
SEm±	0.14	0.10	0.16	0.17
CD (P=0.05)	0.40	0.28	0.47	0.50

Boron content in the grain at harvest is presented in Table -2 and a critical examination of the data revealed that the different sources of boron did not show any significant effect on the boron content of the seed. However, foliar application of solubor recorded highest value (14.13 mg kg^{-1}) of boron content in grain. Among the plots receiving different doses of boron it was found that the boron content in seed in the plots receiving 2.0 Kg B ha^{-1} (14.25 mg kg^{-1}) was significantly higher than other three plots. The boron content in seeds of rest of the three plots was found to statistically at par. Regarding the boron content in the straw at harvest it was found that among different sources, the highest boron content in straw was recorded under plots which received Solubor through foliar application (17.09 mg kg^{-1}). This might be due to the fact that boron is essential for the pollen germination, improves seed yield, increases seed boldness and better root growth. It is also enhances the root nodulation. These results are confirmed by the Mevada *et al.* (2005) [13] and Sharma *et al*. (2005) [18]. Application of boron at different doses significantly affected the content of boron in straw. The content was observed to be highest under plots where 2.0 kg B ha^{-1} was applied (17.22 mg kg^{-1}) which was statistically at par with that under 1.5 kg B ha^{-1} (17.22 mg kg^{-1}) applied plots. This might be due to quick availability of boron to crop during the entire growing period. This result was supported by Praveena (2018) [17].

Total boron uptake by plant

The results revealed that total boron uptake by plant did not vary significantly with the application of various sources through different methods. The highest boron uptake (28.78 g ha^{-1}) was recorded under the Solubor applied through foliar method. Among the doses of boron was concerned, boron uptake increased with increasing B doses resulting in highest uptake at 1.5 kg B ha^{-1} (29.58 g ha^{-1}) and further increase in boron dose of 2.0 kg B ha^{-1} there was decrease in total uptake (28.28 g ha^{-1}). Total uptake at 1.5 kg B ha^{-1} was at par with 2.0 kg B ha^{-1} but significantly superior over the rest of the lower doses. Overall effect of interaction of sources and doses under different methods of application was found to be non-significant.

Table 3: Effect of different sources of Boron and its different doses on Total boron uptake (g ha^{-1}) by plant of black gram

Sources / Doses	S_1 Borax Soil application	S_2 Solubor Foliar application	S_3 Boric acid Soil application	Mean
D_1 0.5 kg ha^{-1}	26.03	27.15	26.53	26.57
D_2 1.0 kg ha^{-1}	27.22	28.39	27.57	27.73
D_3 1.5 kg ha^{-1}	29.22	30.19	29.34	29.58
D_4 2.0 kg ha^{-1}	27.34	29.38	28.12	28.28
Mean	27.45	28.78	27.89	

Sources	SEm (±)	C.D (P=0.05)
S	0.53	NS
D	0.62	1.81
S×D	1.07	NS

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