



ISSN (E): 2277- 7695

ISSN (P): 2349-8242

NAAS Rating: 5.03

TPI 2020; 9(3): 179-184

© 2020 TPI

www.thepharmajournal.com

Received: 24-01-2020

Accepted: 28-02-2020

Rahul Kumar

Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Dr. Ghanshyam

Assistant Professor cum Junior Scientist, Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour Bhagalpur, Bihar, India

Shweta Shambhabhi

Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Sweeti Kumari

Krishi Vigyan Kendra, Katihar, Bihar, India

Alisha Kumari

Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

Corresponding Author:

Rahul Kumar

Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Effect of different sources of boron and it's different doses on boron fractions of the soil

Rahul Kumar, Dr. Ghanshyam, Shweta Shambhabhi, Sweeti Kumari and Alisha Kumari

Abstract

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. It is imperative that application of Zn and B containing fertilizers are needed to exploit the production potential of crops under cropping systems and also to mitigate the deficiencies of these nutrients. Addition of S + Zn + B in balanced fertilization schedule increased N, P and K utilization efficiency which highlights the role of micronutrients in increasing macronutrient use efficiency. Since, maize and black gram are the two important crops which are preferred much for its nutritional quality; the present study "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: S₁: Borax, S₂: Solubor and S₃: Boric acid; Doses: D₁: 0.5 kg ha⁻¹, D₂: 1.0 kg ha⁻¹, D₃: 1.5 kg ha⁻¹, D₄: 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. Therefore, addition of boron fertilizer made more boron nutrient available to the black gram crop. The study of different forms of boron in soil also indicated that most of the soil boron was found in the form of residual boron. The trend of the boron forms in soil was found as residual B > organically bound boron > Oxide bound boron > readily soluble boron > specifically adsorbed boron.

Keywords: Readily soluble boron, residual boron, total boron, solubor, boric acid, correlation

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 (Gupta, 1993; Marschner, 1995) [9, 19]. 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) [3]. A tolerable boron concentration for plants in soils is approximately 25 ppm (Khan 2009) [17]. Generally speaking, there is more boron in the subsoil and deeper (Haas, 1992) [10]. Among micronutrients, B deficiency is wide spread throughout India. 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 N₂ fixation, as B plays a major role in nitrogen assimilation (Brown and Shelp, 1997) [22]. 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) [21].

Reasons behind the boron deficiency are - High soil pH, coarse texture, low organic matter and low moisture content (Pandey and Gupta, 2013) [21].

Boron is very important in cell division, pod and seed formation. 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 (Goldberg, 1997) [7]. Roots of many crops (Such as pulses and oilseeds) may go 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) [6]. 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]. It is imperative that application of Zn and B containing fertilizers are needed to exploit the production potential of crops under cropping systems and also to mitigate the deficiencies of these nutrients. Addition of S + Zn + B in balanced fertilization schedule increased N, P and K utilization efficiency which highlights the role of micronutrients in increasing macronutrient use efficiency. Since, maize and blackgram are the two important crops which are preferred much for its nutritional quality.

Materials and Methods

The study "Relative changes in Boron fractions in black gram rhizosphere" was carried out in 2018 in *kharif* season at BAC Farm, Sabour Bhagalpur. The details of the methods adopted for crop raising, materials used, and criteria adopted for the valuation of treatments during the course of investigation are presented in this chapter.

Climate and weather conditions

The cumulative rainfall recorded was 248.7 mm during the experimental period from August to November, 2018 which was 916.3 mm less than the normal rainfall (1165 mm) for this locality. Rainfall was a bit lower in early part of the crop season and very high in August. However, good drainage facilities of the experimental plot did not pose any problem due to stagnation of water. Relative humidity in the morning hours (7:00 am) and in the afternoon (2:00pm) ranged between 82.6 to 91.6 and 56.9 to 77.7 per cent, respectively. Maximum and minimum temperature recorded for the same period varied in between 28.0 to 34.6 °C and 10.2 to 26.0 °C, respectively. Wind speed varied from 1.4 to 7.2 km hr⁻¹. The key factor influencing the relative duration of vegetative and reproductive growth is the "day length" which ultimately affects the dry matter and yield of the crop. The average duration of bright sunshine did not vary much and the values were 6.2 hours day⁻¹ during the entire Black gram growing period in 2018. Summing up the overall situation it may be said that the weather condition prevailing during *kharif* season of the year 2018 was congenial for raising a Black gram crop.

1. Collection of samples for laboratory work

Soil samples 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

2. Methods of analysis

2.1 Boron fractionation procedure and colorimetric estimation

For Boron fractionation study procedure outlined by Datta *et al.* (2002) [5] was followed where the soil was subjected to sequential extraction procedure as follows. Duplicate samples for each treatment were taken for fractionation study.

2.1.1 Readily soluble boron

Five grams of soil in duplicate were weighed into 50 ml polyethylene centrifuge tubes to which 10ml of 0.01M CaCl₂ was added and shaken for 16 hr (Hou *et al.* 1994, 1996) [11, 12]. After centrifugation at (High speed centrifuge-REMI makes model R 23) 10,000 rpm for 30 min supernatant solution was filtered through Whatman no. 42 filter paper. Boron was determined by clear extracts with Azomethine-H (John *et al.* 1975) [16]. Calcium chloride solution does not interfere with colorimetric estimation of Boron as shown by Datta *et al.* (1998) [4].

2.1.2 Specifically adsorbed boron

The residue from the above step was then extracted with 10 ml of 0.05M KH₂PO₄ by shaking for 1 hr (Hou *et al.* 1994, 1996) [11, 12]. After centrifugation boron was measured in supernatant solution as described in the previous step because KH₂PO₄ was also found not to interfere with the estimation of Boron with Azomethine-H.

2.1.3 Oxide bound boron

The residue from previous step was extracted with 20 ml 0.175M NH₄-oxalate, pH 3.25 by shaking for 1hr (Hou *et al.* 1994, 1996) [11, 12]. Most of the extracts had a yellow to slight reddish colour. The yellow colour was due to Fe and reddish colour was due to slight dissolution of organic matter. Elimination of colour by treating the extracts with NaOH and HClO₄ was done by following procedure. To remove the colour 14 ml aliquot of the extract was taken in 50 ml Teflon beaker and the weight of the beaker plus aliquot was noted. The content was then warmed on hot plate and 2ml of 5N NaOH solution was added to completely precipitate the dissolved Fe as Fe(OH)₃. Jackson (1973) [13] has also suggested a similar procedure to separate Fe and other metals in total elemental analysis of soil and rocks. The beaker with the aliquot was weighted and adjusted by adding distilled water. While doing so, the weight of the 2 ml 5N NaOH was also taken into account. The suspension was filtered through Whatman no. 42 filter paper and thus Fe was separated 9 ml aliquot of the filtrate was taken into a 50ml Teflon beaker and 4ml concentrated H₂SO₄ and 1 ml HClO₄ (60%) were added and heated on hot plate at 135±5 °C to destroy the organic matter. Heating the samples at temperature >140 °C led to B losses (Hou *et al.* 1994, 1996) [11, 12]. Care was also taken not to allow the samples to dry because Boron losses have been reported under these conditions. When the volume was reduced to about 6 ml, HClO₄ was added in an increment of 0.5 ml until the solution became colorless and the volume reduced to 4 to 5 ml. The content was then transferred to a 15 ml graduated polyethylene tube and the final volume was made up to 6 ml. After centrifuging at 10,000 rpm for 15 min, Boron in the clear extracts was determined by the carmine method.

2.1.4 Organically bound boron

The residue from the NH₄-oxalate extraction was treated with 20 ml of 0.5 M NaOH by shaking for 24 hr followed by filtration through Whatman no. 42. The extracts of all samples except sandy soils, were dark in colour due to the dissolution of organic matter. 14 ml of aliquot was taken in a Teflon beaker to destroy the organic matter and the same procedure was followed as described in the case of oxide bound fraction. Final volume was made up to 7 ml. After centrifuging the samples at 10,000 rpm for 15 min, B in the supernatant was determined with carmine.

2.1.5 Residual boron

The residue from previous step was dried and ground. 1 gm subsample was taken into a 50 ml Teflon beaker and few drops of concentrated H₂SO₄, 5 ml of HF (40%) and HClO₄ (60%) were added (Lim and Jackson, 1982) [18]. The beaker was placed on a hot plate at 135±5 °C and the volume reduced to about 3 ml. Then 5 ml of concentrated H₂SO₄ and 5 ml of HF (40%) were added and continued. Further HF was added in increments of 2-5 ml until complete digestion of the soil. After digestion, 3 to 4 ml of HClO₄ (60%) was added depending upon the intensity of colour in the extract to get a clear extract. Finally, the volume was reduced to 3-4 ml by heating to drive off HF and HClO₄ completely. The content was transferred to a polyethylene centrifuge tube and the volume was made up to 25 ml. After centrifuging at 10,000 rpm B in the clear supernatant was determined with carmine. The experimental data recorded in respect of different observations in the present experiment were analyzed statistically with the help of following procedures for Factorial Randomized block design to test the significant of the overall differences among treatment by the F test and

conclusion were drawn at 5% probability level Gomez KA, Gomez AA (1988) [8].

3. Results and Discussions

3.1 Effect of different sources of Boron and its different doses on boron fractions of the soil

3.1.1 Readily soluble Boron (RS-B)

Data related to Readily soluble Boron (RS-B) in the soil is presented in Table. 1 It shows that Readily soluble Boron (RS-B) in soil was not significantly affected due to different sources of boron. The highest boron content in soil resulting from various sources was found with Boric acid and there was increased in Readily soluble B content in soil with the application of different sources and doses of B treated plots over the initial value (0.39 mg kg⁻¹). The different doses of boron significantly increased the Readily soluble Boron (RS-B) status in soil with corresponding enhancement in their doses resulting in highest B content under 2.0 kg B ha⁻¹. The content at 1.5 kg B ha⁻¹ (0.54 mg kg⁻¹) was significantly higher than that at D₁ (0.45 mg kg⁻¹) and D₂ (0.49 mg kg⁻¹) but statistically at par with that under 2.0 kg B ha⁻¹ (0.56 mg kg⁻¹). Regarding the various methods of application it was found that the increase in RS-B was higher under foliar application. A maximum increase of 0.17 mg kg⁻¹ of soil over the initial was observed with the use of different doses of boron. However, the effect of interaction of doses and sources was found to be non-significant. This might be due to a variety of factors such as soil pH, OC, clay minerals, Fe and Al oxides, carbonates and tillage management that change the content of extractable B and transformations among different soil B fractions (Jin *et al.* 1987; Hou *et al.* 1994; Tsalidas *et al.* 1994; Yermiyahu *et al.* 1995) [15, 11, 25].

Table 1: Effect of different sources of Boron and its different doses on Readily soluble Boron (RS-B) (mg kg⁻¹) of the soil

Doses \ Sources	S ₁	S ₂	S ₃	Mean
	Borax Soil application	Solubor Foliar application	Boric acid Soil application	
D ₁ 0.5 kg ha ⁻¹	0.42	0.45	0.47	0.45
D ₂ 1.0 kg ha ⁻¹	0.45	0.48	0.49	0.49
D ₃ 1.5 kg ha ⁻¹	0.52	0.55	0.56	0.54
D ₄ 2.0 kg ha ⁻¹	0.53	0.57	0.58	0.56
Mean	0.48	0.51	0.52	
Sources	S.Em (±)			C.D (P=0.05)
S	0.02			NS
D	0.02			0.06
S×D	0.04			NS

3.2 Specifically adsorbed boron (SA- B)

The data with respect to Specifically adsorbed Boron (SA-B) in the soil tabulated in Table 2 shows that Specifically adsorbed Boron (SA-B) in soil was not significantly affected due to the use of various sources of boron. Among the use of various sources and method of application highest boron content in soil was found under Solubor through foliar method of application. The different doses of boron significantly increased the Specifically adsorbed Boron (SA-B) status in soil and it was found that with corresponding enhancement in their doses there was increase in SA-B content. The highest B content being under 2.0 kg B ha⁻¹. The use of different sources of boron brought about decrease in the average SA-B content as compared to initial. The content

at 1.5 kg B ha⁻¹ (0.34 mg kg⁻¹) was significantly higher than that at D₁ (0.31 mg kg⁻¹) and D₂ (0.32 mg kg⁻¹) but statistically at par with that under 2.0 kg B ha⁻¹ (0.35 mg kg⁻¹). It was also observed that there was no any change in SA-B content of all the plots receiving various doses through different sources and method of boron. A mere change of 0.01 mg kg⁻¹ over the initial status of 0.35 mg kg⁻¹ was observed in D₃S₂ and D₄S₂ plots. Rest of the plots were having either similar SA-B content or decrease SA-B content as compared to initial status. However, the effect of interaction of doses and sources was found to be non-significant. This might be due to higher amount of adsorbed onto clay surfaces in soil (Jin *et al.* 1987) [15]. It is another fraction that is available for plant uptake (Jin *et al.* 1987; Tsalidas *et al.* 1994) [15].

Table 2: Effect of different sources of Boron and its different doses on Specifically adsorbed Boron (SA- 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	0.31	0.30	0.31	0.31
D ₂ 1.0 kg ha ⁻¹	0.31	0.34	0.32	0.32
D ₃ 1.5 kg ha ⁻¹	0.34	0.36	0.32	0.34
D ₄ 2.0 kg ha ⁻¹	0.35	0.36	0.34	0.35
Mean	0.31	0.34	0.32	
Sources	S.Em (\pm)		C.D (P=0.05)	
S	0.01		NS	
D	0.01		0.02	
S×D	0.02		NS	

3.3 Oxide bound Boron (OX- B)

A glance at the data on Oxide bound Boron (OX- B) content in soil presented in Table 3 was found to be non-significant with application of different sources and doses of boron through different method of application. However, there was increase in soil Oxide bound Boron (OX- B) as compared the initial status of 1.61 mg kg^{-1} . Boric acid showed the highest increase among the use of various sources of boron. A mean increase 0.04 mg kg^{-1} was observed with the application Boric acid. Oxide bound Boron (OX- B) content in soil enhanced with increasing B doses up to 1.5 kg B ha^{-1} and further yielded

no positive changes with increase in dose. The highest content of OX-B was found under D₄S₃ plot (1.67 mg kg^{-1}), which was 0.06 mg kg^{-1} higher than the initial status. The combined effect of different sources and doses of boron holds no any significant effect on the OX-B content of soil. This might be due to the fact that Oxide bound fraction is associated with oxides and hydroxides of iron and aluminum and manganese forms the part of structure through isomorphous substitution (McLaren and Crawford 1973) [20]. It is less labile fraction of B, which sorbs B into unavailable forms (Jin *et al.* 2011) [14].

Table 3: Effect of different sources of Boron and its different doses on Oxide bound Boron (OX- 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	1.62	1.61	1.62	1.62
D ₂ 1.0 kg ha ⁻¹	1.64	1.60	1.63	1.62
D ₃ 1.5 kg ha ⁻¹	1.62	1.65	1.65	1.64
D ₄ 2.0 kg ha ⁻¹	1.63	1.63	1.67	1.64
Mean	1.63	1.62	1.64	
Sources	S.Em (\pm)		C.D (P=0.05)	
S	0.03		NS	
D	0.03		NS	
S×D	0.05		NS	

3.4 Organically bound Boron (OR- B)

An examination of data on organically bound Boron content (OR- B) in soil illustrated in Table 4. organically bound Boron (OR- B) was not significantly affected by the different sources as well as doses of boron under various methods of application. However organically bound Boron (OR- B) was found to follow increasing trend with the application of increasing doses of boron over initial status. The use of different sources too increased the OR-B content of the soil however, the effect of different treatment was found to be non-significant. There was an overall increase in all the plots receiving boron through different sources, doses and methods

over the initial content of 2.68 mg kg^{-1} with the highest increment of 0.23 mg kg^{-1} over initial in the plot D₄S₁. Overall the effect of doses and sources as well as its interaction was found to be non-significant. This might be due to the fact that OM in soil gets degraded and may lead to a release of the metal. Organically bound fraction is bound to several forms of OM (detritus, organic coatings on mineral particles, and humus bound fraction) and increase organic carbon in soil leads to increase in OR-B. B adsorbs by the OM (Goldberg 1997) [7] that is in the unavailable form for plant (Hou *et al.* 1994) [11].

Table 4: Effect of different sources of Boron and its different doses on organically bound Boron (OR- 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	2.76	2.76	2.75	2.76
D ₂ 1.0 kg ha ⁻¹	2.78	2.84	2.77	2.80
D ₃ 1.5 kg ha ⁻¹	2.81	2.83	2.78	2.81
D ₄ 2.0 kg ha ⁻¹	2.91	2.78	2.84	2.84
Mean	2.81	2.80	2.79	
Sources	S.Em (\pm)		C.D (P=0.05)	
S	0.04		NS	
D	0.05		NS	
S×D	0.08		NS	

3.5 Residual Boron (RES- B)

An examination of data on Residual Boron (RES- B) in soil presented in Table 5 revealed that Residual Boron (RES- B) was non-significantly affected by the application of different sources as well as doses of boron. It was found that with the application of boron at lower dose under foliar application of solubor there was decrease in the RES-B content of the soil while higher doses resulted in increased content of RES-B over the initial. It was also found that the RES-B content of the soil increased minimally over the initial status in various plots with highest content bearing observed under D₃S₃ (95.49

mg kg⁻¹). Overall it was observed that there was no any significant change in the RES-B of soil with use of various doses, sources, methods as well as their interactions. This might be because Residual fractions are associated with primary and secondary minerals within the crystal structure that is unlikely to be released in the mid- and long-term under the conditions normally found in native (McLaren and Crawford 1973)^[20]. Residual fraction is the non-labile form of B. Mean residual B content increased non-significantly with increase in rate of B application.

Table 5: Effect of different sources of Boron and its different doses on Residual Boron (RES- 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	94.07	91.31	94.18	93.19
D ₂ 1.0 kg ha ⁻¹	94.11	92.83	94.67	93.87
D ₃ 1.5 kg ha ⁻¹	94.74	94.26	95.49	94.83
D ₄ 2.0 kg ha ⁻¹	95.21	95.46	93.64	94.77
Mean	94.53	93.46	94.50	
Sources	S.Em (±)			C.D (P=0.05)
S	1.18			NS
D	1.36			NS
S×D	2.36			NS

4. Relationship among different forms of boron

A close examination of data presented in Table 6 revealed that the Readily soluble Boron (RS-B) was highly and positively correlated with specifically absorbed boron (0.517**) as well as available boron (0.759**) and positively correlated with rest of the fractions of boron. Specifically absorbed boron was highly and positively correlated with available boron (0.631**) and only positively correlated with rest of the fractions of boron. Oxide bound boron was found to be positively correlated with organically bound boron, Residual boron, total boron and available boron. Organically bound and Residual boron was found to have positive but non-significant correlation with all the other forms. Residual boron showed highly positive and significant correlation with Total boron (0.995**). Total boron was found to have positive correlation with all the forms of boron with highly significant correlation with Available Boron (0.339**).

Table 6: Correlation among different forms of boron

	RS-B	SA-B	OX-B	OR-B	RES-B	T-B	AV.B
RS-B	1						
SA-B	0.517**	1					
OX-B	0.220	0.213	1				
OR-B	0.058	0.222	0.263	1			
RES-B	0.126	0.107	0.090	0.125	1		
T-B	0.179	0.153	0.125	0.187	0.995**	1	
AV.B	0.759**	0.631**	0.152	0.145	0.281	0.339*	1

* Significant at 5% and ** Significant at 1% level of significance

References

- Bell RW. Diagnosis and prediction of boron deficiency for plant production. *Plant and Soil*. 1997; 193:149-68.
- Brown PH, Shelp BJ. Boron mobility in plants. *Plant and Soil*. 1997; 193:85-101.
- Carlos B. Effects of Boron on Plants. Nevada's Horticulture Connection. University of Nevada Cooperative Extension, 2000, 1(1).
- Datta SP, Bhadoria PBS, Kar S. Availability of extractable boron in some acid soils, West Bengal, India. *Communications in Soil Science and Plant Analysis*.

- 1998; 29:22852306.
- Datta SP, Ratan RK, Suribabu K, Datta SC. Fractionation and colorimetric determination of boron in soils. *Journal of Plant Nutrition and Soil Science*. 2002; 165:179.
- Dobermann A, Fairhurst T. Nutritional disorders and nutrient management, International Rice Research Institute, Los Banos, Philippines, 2000, 132-34.
- Goldberg S. Reactions of boron with soils. *Plant and Soil*. 1997; 193:35-48.
- Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. John Wiley and Sons, New York, 1988.
- Gupta UC. Factors affecting boron uptake by plants. In *Boron and its role in crop production*, CRC Press Inc. Boca Raton FL, 1993, 87-104.
- Haas E. The Function of Soil Minerals and Trace Elements in Soil, Plant, Animal, and Human Nutrition and Health. *Staying Healthy with Nutrition*. Celestial Arts, 1992.
- Hou J, Evans LJ, Spiers GA. Boron fractions in soils. *Communications in Soil Science and Plant Analysis*. 1994; 25:1841-1853.
- Hou J, Evans LJ, Spiers GA. Chemical fractionation of soil boron. I. Method development. *Canadian Journal of Soil Science*. 1996; 76:485-491.
- Jackson ML. *Soil chemical analysis* prentice Hall India Pvt. Ltd, New Delhi, 1973, 498.
- Jin C, Banuelos GS, Paul JG. Distribution of different forms of boron fractions under different cropping system. *American Journal of Soil Science*. 2011; 51:1025-1031.
- Jin J, Martens DC, Zelazny LW. Distribution and plant availability of soil boron fractions. *Soil Science Society of America Journal*. 1987; 51:1228-1231.
- John MK, Chuah HH, Neufed JH. Application of improved azomethine-H method to the determination of boron in soils and plants. *Anal., Lett. E*. 1975; 5:559-568.
- Khan B. *Environmental Impact and Health Effects of Boron*, 2009. <http://www.articlesbase.com/college-and->

universityarticles/environmental-impact-and-health-effects-of-boron569905.html

18. Lim CH, Jackson ML. Dissolution for total elemental analysis. In A.L. Page *et al.*, (eds.): *Methods of Soil Analysis*. Agronomy 9, Am. Soc. Agron, Soil Sci. Soc. Am., Inc., Madison, Wis, 1982, 1-11.
19. Marschner H. *Mineral Nutrition of Higher Plants*. Aca. Press, San Diego, USA, 1995, 379-396.
20. McLaren RG, Crawford DV. Studies on soil copper. I. The fractionation of Cu in soils. *Journal of Soil Science*. 1973; 24(2):172-81.
21. Pandey N, Gupta B. The impact of foliar boron sprays on reproductive biology and seed quality of black gram, *Journal of Trace Elements in Medicine and Biology*. 2013; 27:58-64.
22. Swaine BJ. The trace elements content of soils. *Common-Wealth Bureau of Soil Sci. (GB), Tech. Common*, 1955, 48.
23. Takkar PN, Randhawa NS. Micronutrient in Indian agriculture. *Fertilizer news*. 1978; 23(8):3-26.
24. Tsadilas CD, Yassoglou N, Kosmas CS, Kallianou C. The availability of soil boron fractions to olive trees and barley and their relationships to soil properties. *Plant and Soil*. 1994; 162(2):211-217.
25. Yermiyahu U, Keren R, Chen Y. Boron sorption by soil in the presence of composted organic matter. *Soil Science Society of America Journal*. 1995; 59:405-409.