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Effect of Sulphur and Boron Levels on Soil Available Nutrients after Harvesting of Sesame (*Sesamum indicum* L.) in Red Soil of Mirzapur

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Authors' contributions

This work was carried out in collaboration between both authors. Author Arvind designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AR managed the analyses of the study and searched the literature. Both authors read and approved the final manuscript.

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ABSTRACT

To study the effect of sulphur and boron on post-harvest soil fertility status, a pot experiment was conducted at Department of Soil Science and Agricultural Chemistry, Institute of Agricultural sciences, Banaras Hindu University, Varanasi during the *kharif* season of 2017 taking sesame as a test crop in red soil of Mirzapur district of Uttar Pradesh. The available nitrogen, phosphorus, potassium, sulphur and boron contents were recorded significantly higher in soil after harvesting of the crop over control. The nitrogen, phosphorus, potash, sulphur and boron content recorded 131.58 kg ha^{-1}, 9.25 kg ha^{-1}, 228.48 kg ha^{-1}, 32.79 kg ha^{-1} and 5.58 mg kg^{-1}, respectively when soil treated with 50 kg S ha^{-1} and 2 kg B ha^{-1} after harvest of the crop. Correlation study of the data shows the a significant and positive interaction between soil properties. Available sulphur was positively correlated with available phosphorus (r = 0.875*) while as organic carbon was also

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significant and positively correlated with available nitrogen (r = 0.935*), phosphorus (r = 0.891*) and potash (r = 0.882*). Multiple regression equation revealed that more than 90% variation in available S was attributed by physicochemical properties of the soil.

Keywords: Sulphur; boron; available nutrients; correlation.

1. INTRODUCTION

Sulphur (S) is a fourth essential element among the 17 essential nutrients required by most of the crops. It plays a key role in augmenting the production and productivity of oilseeds and it has a significant influence on quality of product. It is a constituent of three amino acids (cystine, cysteine and methionine) and thus plays a vital role for protein production [1]. The main sources of sulphur are organic matter, atmospheric deposition and parent material from which soil has been developed. Depletion in organic pools also reduces the carbon content and ultimately influences the soil properties [2]. In recent survey, sulphur deficiency in soil and status of available sulphur in the soils of sesame growing area is depleted in considerable amount because of continuous use of high analysis sulphur less fertilizers coupled with intensive cropping using high yielding varieties and reduction in the use of organic manure. Wide spread sulphur deficiencies have been reported in soils of India [3]. In recent years sulphur and boron deficiency in eastern part of Uttar Pradesh is also reported [4,5].

Boron isa unique among the essential mineral micronutrients because it is the only element that is normally present in soil solution as a non-ionized molecule over the pH range suitable for plant growth. Among the micronutrient deficiency, boron deficiency is the second most dominant problem globally [6]. The importance of boron deficiency has been reported by Chatterjee and Nautiyal [7]. Availability of sulphur in soil significantly increased by the application of gypsum @30 kg ha^{-1} in presence of *Bradyrhizobium* inoculation in clay loam soil as reported by Vijaypriya et al. [8]. Singh and Maan [9] studied the effect of sulphur on groundnut (*Arachis hypogea* L.) and proven the use efficiency of S with increasing level of sulphur. Gupta and Jain [10] revealed that sulphur fertilisation up to 45 kg ha^{-1} significantly increased apparent S recovery in groundnut-wheat system. Availability of N and K_2O content in soils is increased with increase in sulphur level in the soil as reported by Vaghani et al. [11]; Vidyathi et al. [12]; Mathew et al. [13]; Pagal et al. [14]. Viewing above facts, a pot experiment was conducted to study the effect of sulphur and boron levels on fertility status of soil.

2. MATERIALS AND METHODS

To study the effect of sulphur and boron levels on post-harvest physico-chemical soil properties a pot experiment was conducted in red soils of Mirzapur, Uttar Pradesh. Bulk surface (0-15 cm) soil samples were collected from upland area of Rajiv Gandhi South Campus, Barkaccha, Mirzapur, Uttar Pradesh, a sub-campus of Banaras Hindu University, Varanasi. The selected site falls under Vindhyan zone and has an average elevation of 80 m. It lies between the parallels of 23.52° and 25.32° North latitude and 82.7° and 83.33° East longitude with warm climate and an average annual temperature of 26.0°C. This zone receives an average rainfall of 975 mm per annum. A pot experiment was conducted from the collected upland red soil with sesame (var. G-4) during *kharif* season of 2017 in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). After processing the bulk soil samples total 32 pots were taken and filled with 10 kg of soil in each pot. Completely randomized design was laid down with eight treatments: T_1- Absolute control (without fertilizer), T_2- Recommended dose of N, P and K fertilizers @ 60:60:30 kg ha^{-1} (RDF), T_3- RDF + 25 kg S ha^{-1}, T_4- RDF + 50 kg S ha^{-1}, T_5- RDF + 1 kg B ha^{-1}, T_6- RDF + 2 kg B ha^{-1}, T_7- RDF + 25 kg S + 1 kg B ha^{-1}, T_8- RDF + 50 kg S + 2 kg B ha^{-1} with four replications. Two split doses of N and full amounts of P, K, S and B were applied basal as per the treatments at sowing time and mixed in soil uniformly. The sources of N, P and K were Urea, DAP, MOP, gypsum and borax, respectively. Standard procedures were adopted for analysis of soil were as follows: Soil pH [15]; Electrical conductivity [15]; Organic carbon [16]; available N by alkaline permanganate method [17]; available K by ammonium acetate method [18]; available P [19]; 0.15% $CaCl_2$ extractable available S [20] and hot-water soluble available B [21]. Initial soil test values are presented in the Table 1.

Table 1. Initial physico-chemical properties of the experimental soil

Soil test parameter	Initial value	Method
Soil pH (1:2.5)	6.21	Jackson (1973)
Electrical conductivity (1:2.5) dSm^{-1} at 25°C	0.33	Jackson (1973)
Organic carbon (g kg^{-1})	3.3	Walkley and Black (1934)
Available nitrogen (kg ha^{-1})	112.8	Subbiah and Asija (1956)
Available phosphorus (kg ha^{-1})	7.34	Bray and Kurtz (1945)
Available potash (kg ha^{-1})	160.3	Hanway and Heidel (1952)
Available sulphur (kg ha^{-1})	5.75	Williams and Steinberg (1969)
Available boron (mg kg^{-1})	0.54	Berger and Troug (1939)

2.1 Statistical Analysis

The raw data observed during the whole experiment, putted for statistical analysis following the Complete Randomized Design (CRD) to draw the valid differences among the treatments. Correlation and regression analysis were done following data analysis in excel sheet.

3. RESULTS AND DISCUSSION

3.1 Soil pH

Soil pH after the harvest of sesame crop differed significantly over initial pH value (6.21). Soil pH values are presented in Table 2. Data shows that highest pH was found with combined application of sulphur and boron in T_8 (pH 6.87). Effect of sulphur and boron application on soil pH was not found significant. It increases by increasing level of sulphur and boron up to 50 kg S ha^{-1} and 2 kg B ha^{-1}.

3.2 Electrical Conductivity (dS m^{-1})

Electrical conductivity in soil, after the harvest of sesame crop was not significantly influenced by sulphur and boron applications. EC of surface soil at harvest did not differ significantly over initial value (0.33 dS m^{-1}). Slight increase in the EC was observed in T_8 (0.39 dS m^{-1}) which was insignificant with other treatments (Table 2). It might be due to short duration of crop cycle and result is in agreement with the findings of Arbad et al. [22].

3.3 Organic Carbon

The data recorded on organic carbon content (g kg^{-1}) are presented in Table 2. It was noted that levels of sulphur and boron affect the organic carbon in post-harvest soil significantly over the control. It is indicated that 50 kg S ha^{-1} along with 2 kg B ha^{-1} noticed maximum organic carbon in soil (4.13 g kg^{-1}). Organic carbon content under varying levels of boron indicates a significant response with the change in levels of boron from 1 kg B ha^{-1} to 2 kg ha^{-1}. The results were corroborated with Tripathy and Bastia [23].

3.4 Available Nitrogen

Study of data on nitrogen availability in soil after harvest of the sesame as influenced by application of sulphur and boron is presented in the Table 2. The perusal of the data of post harvest soil analysis of sesame was significantly influenced by application of sulphur and boron levels. There was a significant improvement in available nitrogen in the soil crop harvest as compared to initial soil value (112.8 kg ha^{-1}). Maximum available nitrogen (131.58 kg ha^{-1}) was observed in T_8 which was statistically significant over control while statistically at par with other treatments except RDF. The results of present investigation are conformity with results observed by Mathew et al. [13], Pabitra and Haider [24] and Vidyathi et al. [12]. Vaghani et al. [11] reported that the availability of N and K_2O content in soil are increased with increasing in sulphur level.

3.5 Available Phosphorus

Persual of the data on available phosphorus in soil after harvest of the sesame as influenced by application of sulphur and boron are presented in the Table 2. The data of post-harvest soil analysis of available phosphorus revealed the significance of S and B. There was significant improvement in available phosphorus in the soil after the crop harvested as compared to initial soil status (7.34 kg ha^{-1}). Available phosphorus increased with RDF along with 50 kg S ha^{-1} (8.57 kg ha^{-1}) compared to sole application of RDF (7.41 kg ha^{-1}) and control (5.27 kg ha^{-1}). The combine application of sulphur and boron levels up to 50 Kg S ha^{-1} and 2 kg B ha^{-1} increases phosphorus availability (9.25 kg ha^{-1}) after harvest of sesame and was found to be significant and more available as compared to control. Results are conformity with result observed by Kumar et al. [25].

3.6 Available Potassium

Data pertaining to available potassium in soil after harvest of the sesame is presented in the Table 2. The perusal of the data of post harvest soil analysis of available potassium in soil revealed the importance of sulphur and boron application in soil. There was significant improvement in available potassium in the soil after the crop harvested as compared to initial soil status (160.3 kg ha^{-1}). Available potassium was increased when treated with RDF along with 50 kg S ha^{-1} (216.72 kg K ha^{-1}) and 25 kg S ha^{-1} (212.80 kg K ha^{-1}) application compared to sole application of RDF (179.40 kg K ha^{-1}) and control (161.56 kg K ha^{-1}). The soil potassium after crop harvest was found higher in combined application of sulphur and boron up to 50 kg S ha^{-1} and 2 kg B ha^{-1} (228.48 kg K ha^{-1}) after harvest of sesame but at par with T_7. Similar result was reported by Devi et al. [26] and Laxminarayan and Patiram [27].

3.7 Available Sulphur

The data on post harvest soil analysis of available sulphur of sesame was significantly influenced by the application of sulphur and boron levels. There was increase in the available sulphur content with application of RDF along with 50 kg S ha^{-1} (30.44 kg S ha^{-1}) and 25 kg S ha^{-1} (23.72 kg S ha^{-1}) followed by application of boron levels 2 kg B ha^{-1} (18.98 kg S ha^{-1}) and 1 kg B ha^{-1} (15.99 kg S ha^{-1}) as compared to application of RDF alone (12.27 kg S ha^{-1}) and control (9.18 kg S ha^{-1}) (Table 2). The soil sulphur after crop harvest was found higher in combined effect of sulphur and boron up to 50 kg S ha^{-1} with 2 kg B ha^{-1} (32.79 kg S ha^{-1}) and availability of sulphur after harvest of sesame was found to be significant. It might be due to the use of higher dose of S and B in soil which increased the availability of the S in soil. Increased levels of S and B influenced the S status in the soil. Similar results were found by Bhagyalakshmi et al. [28]. Application of gypsum @30 kg ha^{-1} in presence of *Bradyrhizobium* inoculation significantly increases the availability of sulphur in clay loam soil as reported by Vijaypriya et al. [8]. Singh and Maan [9] studied the effect of sulphur (0, 20, 40 and 60 kg ha^{-1}) on groundnut (*Arachis hypogea* L.) and the use efficiency of S with increase in the level of S, and maximum S use efficiency was recorded at lower levels of S application. Gupta and Jain [10] reported that continuous sulphur application increased the available S status in soil when S applied @30 and 45 kg ha^{-1}.

3.8 Available Boron

Perusal of the data on available boron in the soil after harvest of the crop as influenced by application of sulphur and boron is presented in Table 2. There was a significant improvement in available boron in the soil after the crop harvest as compared to initial soil (0.54 mg kg^{-1}). There was increase in the available boron content with application of RDF along with 50 kg S ha^{-1} (1.49 mg g^{-1}) and 25 kg S ha^{-1} (1.56 mg kg^{-1}) and followed by application of boron levels up to 2 kg B ha^{-1} (5.31 mg kg^{-1}) and 1 kg B ha^{-1} (4.68 mg kg^{-1}) as compared to application of RDF alone (1.34 mg kg^{-1}) and control (1.16 mg kg^{-1}). Increased level of B influenced the boron status and its increment in the soil. Similar results were found by Sarkar et al. [29]. Mathew et al. [13] revealed that application of sulphur up-to 30 kg ha^{-1} increased the availability of soil nutrients including sulphur and boron. Pabitra and Haider [24] found that application of boron increased the content of hot water soluble boron in soil due to beneficial sffects of liming on boron recovery in the given soil. Synergistic effect of sulphur and boron were recorded in the available nutrient status by the application of these nutrients as reported by Mathew et al. [13].

3.9 Correlation of Available S with Soil Properties

The relationship of the amount of sulphate sulphur extracted (0.15% $CaCl_2$) with the physico-chemical properties of the soil and regression analysis have been studied for post-harvest soils and presented in Tables 3 and 4, respectively. Available S was well correlated with the soil properties. These observations were substantiated by the significant positive correlation of available S with available P and organic carbon of the soil. These observations corroborate the finding of Das et al. [30]. Correlation studies indicated positive and significant correlation of available S with P (r =0.875*) and organic carbon content of the soil (r = 0.882*). The multiple regression equations revealed that 100 % variation in available S was attributable to the collective effect of soil physico-chemical properties. Soil pH, EC and organic carbon collectively accounted for about 84.4% variation in available S. This observation is in

Table 2. Effect of sulphur and boron levels on pH, electrical conductivity, organic carbon, available N, P, K, S and B content on post-harvest soil

Treatment	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	B ($mg\ kg^{-1}$)
Control	6.69	0.35	3.40	112.33	5.27	161.56	9.18	1.16
RDF	6.74	0.37	3.73	125.01	7.50	179.40	12.27	1.34
RDF + 25 kg S ha^{-1}	6.66	0.38	3.85	127.05	7.41	212.80	23.72	1.56
RDF + 50 kg S ha^{-1}	6.70	0.37	4.05	131.17	8.57	216.72	30.44	1.49
RDF + 1 kg B ha^{-1}	6.77	0.36	3.93	129.06	6.97	218.68	15.99	4.68
RDF + 2 kg B ha^{-1}	6.70	0.37	3.75	128.37	7.86	218.60	18.98	5.31
RDF + 25 kg S ha^{-1} + 1 kg B ha^{-1}	6.76	0.38	4.00	129.84	9.04	225.40	27.08	4.64
RDF + 50 kg S ha^{-1} + 2 kg B ha^{-1}	6.87	0.39	4.13	131.58	9.25	228.48	32.79	5.58
SEm (±)	0.04	0.013	0.13	1.90	0.24	5.84	0.982	0.09
CD (P=0.05)	0.118	NS	0.383	5.60	0.70	17.16	2.892	0.263

Table 3. Correlation of available S amongst various soil properties

Soil Parameter	S	pH	EC	OC	N	P	K	B
S ($kg\ ha^{-1}$)	1							
Soil pH	0.402	1						
EC ($dS\ m^{-1}$)	0.810**	0.478	1					
OC ($g\ kg^{-1}$)	0.882*	0.569	0.756**	1				
N ($kg\ ha^{-1}$)	0.771**	0.425	0.728**	0.935*	1			
P ($kg\ ha^{-1}$)	0.875*	0.527	0.867*	0.891*	0.882*	1		
K ($kg\ ha^{-1}$)	0.809**	0.407	0.696	0.882*	0.913*	0.807**	1	
B ($mg\ kg^{-1}$)	0.375	0.658	0.412	0.494	0.540	0.515	0.712**	1

*** And * significant at 5 and 1% level, respectively*

Table 4. Effect of soil properties on predictability of available sulphur

Regression equation	R^2
Y= (Available S) -333.45 +52.66 Ph	R^2= 0.16
Y(Available S)= -201.239 + 2.628 pH + 551.763 EC	R^2= 0.656
Y(Available S)= -20.172 -22.421 pH +243.896 EC + 26.451 OC	R^2= 0.844
Y (Available S) = 97.777 -37.988 pH +277.344 EC +52.978 OC -1.007 N	R^2= 0.902
Y (Available S) = 199.370 -41.802 pH -127.766 EC + 49.290 OC -1.263 N + 3.406 P	R^2= 0.929
Y (Available S) = 237.673 -40.218 pH +93.567 EC + 44.671 OC -1.691 N +3.914 P +0.153 K	R^2= 0.957
Y (Available S) = -3496.907 +649.407 pH -1060.680 EC -341.553 OC + 0.382 N +17.750 P+ 3.652 K-28.041 B	R^2= 1.000

close agreement with that of Borkotoki and Das [31]. Electrical conductivity had significant and positive correlation with available P (r =0.867*), while as organic carbon had significant and positive correlation with available P (r =0.891*) and K (r = 0.882*). The regression analysis shows that soil pH, EC, N, P and K contributed 92.9% variation in soil available S while inclusion of K improved the contribution level to 95.7%.

4. CONCLUSIONS

From the present study it can be concluded that application of boron @ 2 kg ha^{-1} resulted significant evidence on increasing available potash in soil after harvesting of sesame crop. However, sulphur levels got a significant relationship with available nitrogen, phosphorus and potash in soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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