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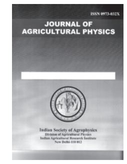

Effect of different levels of sulphur and biofertilizer on the yield of Indian mustard (*Brassica juncea* L.) and soil properties

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ABSTRACT

Present paper reports the results of the study on the effect of varying levels of sulphur (S_0, S_{20}, S_{40} and S_{60} kg ha^{-1}) as gypsum and source of biofertilizer @ 200 g/10 kg of seed inoculated B_1 (Azotobacter) on yield of mustard crop and soil properties. The grain yield (q/ha) was significantly increased by the application of both sulphur and source of biofertilizer. The maximum yield was obtained by the sulphur application @ 40 kg/ha and by the source of biofertilizer (B_1) @ Azotobacter /10 kg seed inoculate. The interaction between sulphur and biofertilizer was significant and the maximum increase in yield was obtained by applied sulphur @ 40 kg ha^{-1} at biofertilizer (B_0, B_1) 0 and 200 g Azototobacter/10 kg seed inoculate. The soil samples collected after harvest of mustard crop showed the slight decrease in pH and EC and increase in organic carbon, available nitrogen, phosphorus, potassium and sulphur was recorded by the application of sulphur and biofertilizer applied alone or in conjunction with each other.

Key words: Sulphur, Gypsum, Azotobacter, Mustard, Soil properties

Introduction

The oilseed form essential part of human diet. Besides it produces basic raw materials for agro-based industries and has large acreage covering 20.7 million ha under various oilseeds in different agro-climatic zones of this country. The average Indian consumer uses relatively low quantities of edible oil, no doubt influenced by his modest level of income. The annual per capita "disappearance" of oils and fats in 1999 was as high as 82.3 kg in Malaysia, 47 kg in USA, 45.8 in EU-15, 17.3 kg average for the world as a whole and 11.9 kg in China as against 9.9 kg in India. This has been primarily due to phenomenal increase in human population and lower rate of productivity of these crops. Rapeseed and mustard are the major *Rabi* oilseed crops of India and stand next to groundnut in the oilseed economy. Rapeseed and mustard are one of the most important edible oils of northern and eastern parts of India.

Various nutrients and micronutrients are required for oilseed production, but the nutrient which plays a multiple role in providing nutrition to oilseed crops, particularly those belonging to cruciferae family is sulphur. Each unit of fertilizer sulphur generates 3-5 units of edible oil, a commodity needed by every family. Sulphur can be rightly called as fourth major element of the plant because it is a constituent of three amino acids and helps in the formation of chlorophyll and synthesis of oils. Sulphur application also has marked effect on soil properties and is used as soil amendment to improve the availability of other nutrients in soil as gypsum and pyrite. Sulphur is the cheapest of the four major plant

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nutrients today. Between the two common sources of sulphur, a relatively large deposit of gypsum are available in India and is a cheap source of sulphur, hence could also be better source of sulphur for oilseed crops. Khan and Hussain (1999) showed the highest seed and oil yield in mustard (*Brassica juncea*) cv. Kranti, Varuna and Rohini was obtained by applying 20 kg sulphur per hectare. Biofertilizers are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco-friendly but can not at any cost replace chemical fertilizers that are indispensable for getting maximum crop yields. They supplement chemical fertilizers for meeting the integrated nutrient demand of the crops. Azotobacter inoculants when applied to many non-leguminous crop plants, promote seed germination and initial vigor of plants by producing growth promoting substances. Application of biofertilizers results in increased mineral and water uptake, root development, vegetative growth and nitrogen fixation. Therefore, present study deals with the combined effect of sulphur and biofertilizer on yield of mustard crop and soil properties.

Materials and Methods

Field experiment was conducted on the Soil and Environmental Science Crop Research Farm of Allahabad Agricultural Institute, Deemed University, Allahabad (U.P.) during *Rabi* season of 2003-04. The surface soil samples (0-15 cm) collected from the experimental site were analyzed for physico-chemical characteristics as suggested by Jackson (1973) and results are summarized in Table 1. Mustard cultivar 'Varuna' was tested for four levels of sulphur, i.e., 0, 20, 40 and 60 kg ha^{-1} and two levels of biofertilizer (Azotobacter) i.e., 0 and 200 g/10 kg seed inoculate. Irrigation scheduling, fertilizer application and intercultural operations were followed as per normal agronomic practices. The experiment was laid out in 4 X 2 factorial R.B.D. with 8 treatments and three replications. Grain yield was recorded at harvest for all the treatments. At harvest of crops, surface soil samples were collected and analyzed for textural classes, pH, EC, organic carbon, sulphur and available N, P, K as per standard laboratory methods (Jackson, 1973).

Table 1. Pre-sowing mechanical and chemical analysis of soil properties at 0-15 cm depth of soil

Sl. No.	Soil Properties	Rating
1.	Soil texture	Sandy loam
2.	Soil pH (1:2)	7.7
3.	Soil EC (dS m^{-1})	0.32
4.	Organic carbon (%)	0.34
5.	Available nitrogen (kg ha^{-1})	238.22
6.	Available phosphorus (kg ha^{-1})	21.07
7.	Available potassium (kg ha^{-1})	233.33
8.	Available sulphur (ppm ha^{-1})	16.24

Results and Discussion

Grain yield of mustard crop: The average seed yield had significant effect of sulphur levels at crop harvest. The yield increased progressively and significantly with each successive doses of sulphur application. In S_0 level of sulphur, the seed yield was 16.83 as against 18.33, 19.33 and 18.87 q ha^{-1} recorded in $S_{20,}$ S_{40} and S_{60} levels of sulphur, respectively. Thus, the difference in yield resulting from S application was significant. The results are summarized in Table 2. Similar results have been reported by Raj *et al*. (1998). The seed yield of 19.02 q ha^{-1} from plants emerging from biofertilizer inoculated seeds (B_1) recorded consistently and significantly greater than seed yield of 17.66 q ha^{-1} in plants from biofertilizer

Table 2. Effect of different levels of sulphur, biofertilizer (Azotobacter) and their interaction on yield (q ha^{-1}) of mustard crop

Levels of Sulphur	Biofertilizer (Azotobacter)		Mean (S)
	B_0	B_1	
S_0	16.66	17.00	16.83
S_1	17.33	19.33	18.33
S_2	18.66	20.00	19.33
S_3	18.00	19.73	18.87
Mean (B)	17.66	19.02	-
	F-test	S. Em. ±	C.D. at 5%
Sulphur (S)	S	0.072	0.219
Biofertilizer (B)	S	0.051	0.155
Interaction (S x B)	S	0.102	0.310

uninoculated seeds (B_0). Similar result has been reported by Kumar and Kumar (1994).

The interaction between sulphur levels and biofertilizer inoculation on grain yield was significant. The application of sulphur @ 60 kg ha^{-1} in conjunction with Bo and B_1 treatments was 18.0 and 19.73 q ha^{-1} and corresponding grain yield at 40 kg S ha^{-1} in conjunction with B_0 and B_1 treatments was 18.66 and 20.0 q ha^{-1}. The plants emerging from biofertilizer inoculated seeds recorded significantly higher seed yield than plants emerging from biofertilizer uninoculated seeds. Chauhan *et al*. (1996) also reported an increase in seed yield.

Effect of different treatments on chemical properties of soil: The different treatments of sulphur and biofertilizer tended to have a marked effect on the properties of soil at crop harvest.

(i) Soil reaction: The soil pH (1: 2 w/v) after crop harvest was in order of $S_0 > S_{20} > S_{40} > S_{60}$. The soil pH tended to decrease with the progressive increase in added sulphur, but the difference was slightly significant. As gypsum fertilizer is slightly acidic in nature, so some bases were progressively neutralized. Minimum pH of soil after crop harvest was recorded in S_{60} level of sulphur and the maximum was found in S_0 level of sulphur. The plots sown with biofertilizer inoculated seeds (B_1) recorded lower pH (7.53) than Bo levels 7.57 and the difference was significant.

(ii) Electrical conductivity: There was significant effect of sulphur levels on the EC of soil water suspension (1:2 w/v) after crop harvest. The EC of soil was however, significantly reduced (0.228) by sulphur applied @ 60 kg ha^{-1} whereas without application of sulphur (0 kg ha^{-1}) resulted in significant highest EC (0.305). The increasing of EC was rather minor, as the soil salinity was not materially altered to cause any salinity problem. EC of plots sown with biofertilizer inoculated seeds (B_1) was on the average 0.263 dSm^{-1} at 25^0C lower than EC of plots (0.271) sown with biofertilizer uninoculated seeds (B_0). The decreases proved to be significant.

(iii) Organic carbon: Percent organic carbon in soil after crop harvest increased significantly with each successive dose of added sulphur. As increase in percent organic carbon over S_0 level of sulphur (0.34 %) was obtained by S_{40} level (0.39%). With the application of sulphur @ 60 kg ha^{-1} the percent organic carbon reduced slightly (0.38 %) and result was significant as judged by the critical difference at 5 % level of significance. The percent organic carbon in B_1 and B_0 was 0.39 and 0.36%, respectively. Although the difference between B_1 and B_0 in respect of percent organic carbon was 0.03 yet it was significant.

(iv) Available nitrogen (kg ha^{-1}): The available nitrogen in soil after crop harvest was significantly influenced by sulphur levels, the sulphur applied @ 40 kg ha^{-1}. Each successive dose of sulphur resulted in significant increase in available nitrogen. The maximum nitrogen concentration (256.445 kg ha^{-1}) was recorded in S_{40} level of sulphur while the minimum (237.967 kg ha^{-1}) was in S_0 level. The B_1 level of biofertilizer inoculation recorded greater amount of available nitrogen (254.473 kg ha^{-1}) in soil after crop harvest than B_0 level (242.645 kg ha^{-1}) sown with biofertilizer uninoculated seeds. It appears so by the results of enhanced root residues and exudates incorporated in the soil at B_1 levels (Table 3).

Table 3. Effect of different levels of sulphur, biofertilizer (Azotobacter) and their interaction on available nitrogen (kg ha^{-1}) in soil after crop harvest

Levels of Sulphur	Biofertilizer (Azotobacter)		Mean (S)
	B_0	B_1	
S_0	235.37	240.57	237.967
S_1	242.35	253.20	247.775
S_2	247.56	265.33	256.445
S_3	245.31	258.79	252.048
Mean (B)	242.645	254.473	-
	F-test	S. Em. ±	C.D. at 5%
Sulphur (S)	S	1.004	3.044
Biofertilizer (B)	S	0.710	2.153
Interaction (S x B)	S	1.419	4.305

Table 4. Effect of different levels of sulphur, biofertilizer (Azotobacter) and their interaction on available phosphorus (kg ha^{-1}) in soil after crop harvest

Levels of Sulphur	Biofertilizer (Azotobacter)		Mean (S)
	B_0	B_1	
S_0	21.07	24.87	22.97
S_1	27.13	28.20	27.67
S_2	28.53	30.33	29.43
S_3	25.13	25.40	25.27
Mean (B)	25.47	27.20	-
	F-test	S. Em. ±	C.D. at 5%
Sulphur (S)	S	0.153	0.463
Biofertilizer (B)	S	0.108	0.327
Interaction (S x B)	S	0.216	0.655

(v) Available phosphorus (kg ha^{-1}): The data regarding the content of available phosphorus in soil after crop harvest is given in Table 4. The available phosphorus in sulphur treated plots increased progressively with the increases in level of added sulphur in soil after crop harvest. The available phosphorus in soil was in order of S_{40}>S_{20}>S_{60}>S_0. Each level of sulphur increased the available phosphorus in soil significantly. Maximum available phosphorus (29.43 kg ha^{-1}) was recorded in S_{40} level of sulphur while the minimum (22.97 kg ha^{-1}) was in S_0 level. The B_1 level of biofertilizer inoculation recorded greater amount of available phosphorus in soil after crop harvest (27.20 kg ha^{-1}) than B_0 level i.e., sowing of biofertilizer uninoculated seeds (25.47 kg ha^{-1}).

(vi) Available potassium (kg ha^{-1}): The available potassium in soil increased significantly by the successive dose of added sulphur. Consequently, the available potassium in soil was in order of S_{40}>S_{60}>S_{20}>S_0. The maximum available potassium (252.148 kg ha^{-1}) was recorded at S_{40} level of sulphur application while the minimum (232.830 kg ha^{-1}) was recorded at S_0 level. The B_1 level of biofertilizer inoculation recorded significantly greater amount of available potassium in soil after crop harvest (250.220 kg ha^{-1}) than B_0 level i.e., sowing of biofertilizer uninoculated seeds (237.732 kg ha^{-1}). The difference in available potassium was found to be significant (Table 5).

Table 5. Effect of different levels of sulphur, biofertilizer (Azotobacter) and their interaction on available potassium (kg ha^{-1}) in soil after crop harvest

Levels of Sulphur	Biofertilizer (Azotobacter)		Mean (S)
	B_0	B_1	
S_0	230.33	235.33	232.830
S_1	238.22	248.33	243.277
S_2	242.19	262.11	252.148
S_3	240.19	255.11	247.648
Mean (B)	237.732	250.220	-
	F-test	S. Em. ±	C.D. at 5%
Sulphur (S)	S	0.424	1.286
Biofertilizer (B)	S	0.300	0.909
Interaction (S x B)	S	0.600	1.819

(vii) Available sulphur (ppm): The available sulphur in ppm increased significantly by the successive dose of added sulphur. The highest dose of added sulphur in S_{60} level of sulphur application and result was significantly increased in available sulphur as compared to lower levels (S_0) of added sulphur. The maximum available sulphur in soil after crop harvest (22.90 ppm) was recorded at S_{60} level while the minimum (16.18 ppm) was at S_0 level. The B_1 level of biofertilizer inoculation recorded greater amount of available sulphur (20 ppm) in soil after crop harvest than B_0 level (19.48 ppm), i.e. sowing of the biofertilizer uninoculated seed (Table 6).

Table 6. Effect of different levels of sulphur, biofertilizer (Azotobacter) and their interaction on available sulphur (ppm) in soil after crop harvest

Levels of Sulphur	Biofertilizer (Azotobacter)		Mean (S)
	B_0	B_1	
S_0	16.23	16.13	16.18
S_1	18.20	18.19	18.20
S_2	21.25	22.13	21.69
S_3	22.24	23.55	22.90
Mean (B)	19.48	20.00	-
	F-test	**S. Em. ±**	**C.D. at 5%**
Sulphur (S)	S	0.176	0.534
Biofertilizer (B)	S	0.124	0.377
Interaction (S x B)	S	0.249	0.755

Conclusions

On the basis of aforesaid findings, it could be concluded that sulphur @40 kg ha^{-1} and biofertilizer @200 g Azotobacter per 10 kg seed inoculated (S_2B_1) treatment combination was the best treatment as compared to others. There is a need to verify the results in multi-location trials across the country following diverse soil and climatic conditions.

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