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Responses of Calcium and Sulfur on Growth and Yield of Indian Mustard (*Brassica juncea* L. Czern & Coss)

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Abstract An experiment were carried out to study the effect of different levels calcium and sulfur application on the performance of Indian mustard variety Pusa bold during the *rabi* season of 2014-15 in randomize block design (RBD) on red soil. Application of calcium and sulfur had significantly influenced the plant height, number of leaf, number of branches and number of siliqua significantly increased over control. Highest plant height (151.8 cm), number of leaves (21.9), number of branches per plant (11.3), secondary branches/plant (9.35), number of siliqua per plant (117.2), grain yield (18.7 q ha^{-1}), stover/stalk yield (44.7 q ha^{-1}) and 1000 seed weight (6.24 g) were recorded with the application of 25 kg calcium + 25 kg sulfur ha^{-1} in the form of lime and sulfur. As basal application of calcium and sulfur in different treatment on mustard crop significantly increase protein content and oil percentage over control. Lime reduced soil acidity and increase soil pH towards neutral range due to root zone acidification.

Keywords Calcium, Sulfur, Physico-chemical property, Plant height and branches, Protein content.

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Introduction

Indian mustard (*Brassica juncea* L. Czern and Coss) popularly known as rai, raya or laha is one of the most important oil seed crops of the country and it occupies considerably large acreage among the *Brassica* group of oil seed crops. It has 38 to 42% oil and 24% protein. India produced 8.3 million tones of rapeseed-mustard in 2013-14 from an area of 6.6 million hectares with an average yield of 1,250 kg/ha [1]. The major mustard producing states are Rajasthan Haryana, Madhya Pradesh, Uttar Pradesh, West Bengal and Gujarat which together account for about 86.5% area and 91.4% production during 2012-13 [1]. Mirzapur district of Uttar Pradesh is situated in Vindhya Plateau Zone and it has a sizable area under Indian mustard cultivation but the productivity level is very low. The reasons for low productivity are poor knowledge about newly released crop production technologies with nutrient management in the farmers' field.

Table 1. Physico-chemical properties of experimental soil.

Sl. No.	Properties	Contents
Physical properties		
1.	Bulk density (mg m^{-3})	1.36
2.	Particle density (mg m^{-3})	2.21
3.	Water holding capacity (%)	42.3
4.	Porosity (%)	48
5.	Sand (%)	11
7.	Clay (%)	41
8.	Soil texture	Red sandy
Chemical properties		
1.	Soil reaction (pH)	6.8
2.	Electrical conductivity	0.66
3.	Organic carbon	0.39
4.	Available nitrogen (kg ha^{-1})	173.3
5.	Available phosphorus (kg ha^{-1})	11.9
6.	Available potassium (kg ha^{-1})	160.3
7.	Available sulfur (kg ha^{-1})	9.3

Calcium (Ca) is very essential in the formation of plant's cell membrane. It forms middle lamellae of cells as calcium pectate. Middle lamella is helpful in the iterance of all nutrients except harmful elements. Calcium enhance the uptake of nitrate nitrogen and therefore is interrelated with nitrogen metabolism. Due to being a part of cell membrane makes straw and stalk hard. It increases the activity of bacteria found in nodules of leguminous crops and thus enhances nitrogen fixation in soil [2].

The deficiency of sulfur (S) is emerging fast in areas under continuous use of sulfur free fertilizer like diammonium phosfate and urea [3]. Sulfur is the fourth major plant nutrient after nitrogen, phosphorus and potassium for Indian agriculture. It is essential for synthesis of amino acids, proteins, oils, a component of vitamin A and activates enzyme system in plant. Three amino acids viz., methionine (21% S), cysteine (26% S) and cystine (27% S) contain S which are the building blocks of proteins. About 90% of sulfur is present in these amino acids. Sulfur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in oilseeds. Adequate sulfur is therefore very much crucial for oilseed crops. Sulfur is also a constituents of vitamins biotine and thiamine (B1) and also of iron sulfur proteins called ferrodoxins. Sulfur is associated with the production of oilseed crops of superior nutritional and market quality [4]. It also helps in the reduction-oxidation reactions in the respiration. Sulfur deficiencies in India are widespread and scattered. Deficiency of sulfur in Indian soils is on increase due to intensification of agriculture with high yielding varieties and multiple cropping coupled with the use of high analysis sulfur free fertilizers along with the restricted or no use of organic manures have accrued in depletion of the soil sulfur reserve. Sulfur deficiency has been reported by several scientists in cereals, pulses, oil seeds [5] and bulb crops [6]. As per latest available data 41% tested soil samples were deficient in available sulfur in the country [7—9]. The importance of calcium and sulfur application in increasing crop production has been recognized in India, but the work has been mostly confined to fruit trees and vegetable crops. The information regarding the application of calcium and sulfur in Indian mustard is very meager and fragmentary particularly for Eastern Uttar Pradesh. Keeping the above facts in view an attempt has been made to study the effect of Ca and S application on growth and yield attributes characters of Indian mustard.

Materials and Methods

The field experiment was carried out during *rabi* season of 2014-15 on red soil at the crop cafeteria of Banaras Hindu University- Krishi Vigyan Kendra, Rajiv Gandhi South Campus, Barkachha, Mirzapur. The field selection had been under Groundnut-okra cropping system. The Pusa Bold variety of mustard was selected for present experiment. The physico-chemical properties of experimental soil had been present in Table 1. The experiment was laid out in randomized block design (RBD) comprising five treatments with four replications. The treatments was consisted as application of Calcium @ 25 kg ha^{-1}, Sulfur @ 25 kg ha^{-1} alone and also combination of Calcium @ 25 kg ha^{-1} + Sulfur @ 25 kg ha^{-1} and Calcium @ 20 kg ha^{-1} + Sulfur @ 20 kg ha^{-1} were made. One control plot was kept as application of @ 50 kg N and 50 kg P ha^{-1} for comparative study. Recommended doses of

Table 2. Effect of different treatments on plant height, leaves/plant, branches/plant and siliqua/plant of mustard.

Treatments	Plant height (cm) (DAS) 40	60	80	Leaves/plant (DAS) 40	60	80	Branches/plant 60	80	Siliqua/ plant
Control (farmers practices)	21.85	96.3	120.0	7.6	15.5	15.8	5.5	5.7	45.8
25 kg Ca ha^{-1}	23.90	99.0	127.4	7.7	17.5	17.8	7.5	7.6	63.8
25 kg S ha^{-1}	25.60	98.0	128.3	7.9	18.4	18.8	7.8	7.9	101.2
25 kg Ca + 25 kg S ha^{-1}	27.52	115.6	151.8	9.1	21.3	21.9	9.7	11.3	117.2
20 kg Ca + 20 kg S ha^{-1}	26.20	105.4	143.4	8.1	18.7	19.0	8.6	9.3	105.6
SEm ±	0.38	0.63	0.33	0.30	0.30	0.28	0.26	0.14	0.22
CD (p=0.05)	1.07	1.92	1.03	0.94	0.99	0.81	0.81	0.44	0.68

N, P and K (90, 60 and 40 kg ha^{-1}) were applied in each treatment. Half of the nitrogen and full doses of phosphorus and potassium were applied as basal dose at the time of sowing by placement method. The remaining half of the nitrogen was applied at the time of first irrigation. The plant height, number of leaves and number of branches were recorded at 40, 60 and 80 days after sowing of crops. Days to 50% flowering data was recorded days after sowing and number of siliqua/plant, secondary branches/plant, and 1,000 seed weight were recorded after harvesting of crops. All the cultural practices were followed as per the standard recommended practices. The initial soil samples were collected from experimental field before start of the experiment. Composite soil sample was collected at flowering and at harvest from each experimental plot from 0 to 15 cm depth. The soil was mixed thoroughly and samples of about 0.5 kg were obtained by quartering technique and stored in neatly labeled polythene bags for soil analysis. Collected soils were sieved in a 2 mm mesh removing root hair as much as possible and assayed for bulk density and particle density of soil samples were determined by using specific gravity bottle. Water holding capacity of soil was determined by Keen Rozkowski box method.

Soil pH was recorded with the help of glass electrode digital pH meter. EC, organic carbon, available nitrogen, available phosphorus, available potassium and available sulfur were also recorded by Singh and Singh [10]. Protein content was calculated by multiplying N content by the factor 6.25. Oil content in seed was determined by sox let extraction using petroleum ether as an extracting. The harvested crop from each net plot was bundled separately and sun dried for 4 days and threshed. The threshed grains were cleaned and sun dried to a constant weight before recording final grain yield (kg ha^{-1}).

Results and Discussion

A considerable amount of variation was observed in most of the characters. The data presented in Table 2 indicated that application of calcium and sulfur alone and in combination resulted in significantly higher plant height, number of branches and number of leaves over control. Highest plant height)151.8 cm) was recorded with the application of Ca @ 25 kg + S @ 25 kg ha^{-1}. It is evident from the data that the height of plant at 40 and 60 days after sowing ranged was 21.85 to 27.52 and 96.3 to 115.6 cm respectively. The maximum plant height was recorded with combination of Ca @ 25 kg + S @ 25 kg ha^{-1} and lowest in the control plot. The data related to number of leaves per plant were recorded at different stages of plant growth. Highest plant leaves per plant (21.9) were recorded with the application of treatment combination of Ca @ 25 kg + S @ 25 kg ha^{-1} and minimum number of leaves per plant attained in control plot (15.8). At 40 and 60 days after sowing the number of leaves per plant varied from 7.6 to 9.1 and 15.5 to 21.3. Maximum number of branches/plant (11.3) and siliqua/plant (117.2) was obtained in plots which received Ca @ 25 kg + S @ 25 kg ha^{-1} as in combination with recommended dose of fertilizers. The minimum number of branches/plant and siliqua/plant (5.7 and 45.8) produced in control plots. The improvement in the yield attributes viz. plant height, leaves/plant, branches/

Table 3. Effect of different treatments on days to 50% flowering, secondary branches/plant and 1,000 seed weight of mustard.

Treatments	Days to 50% flowering (days after sowing)	Secondary branches/ plant (no.) (at \ harvesting stage)	1000-seed weight (g)
Control (farmers practices)	37.25	6.15	1.39
25 kg Ca ha^{-1}	42.41	7.55	1.79
25 kg S ha^{-1}	46.19	8.45	3.28
25 kg Ca + 25 kg S ha^{-1}	51.55	9.35	6.24
20 kg Ca + 20 kg S ha^{-1}	49.09	8.70	4.21
SEm ±	0.529	0.191	0.047
CD (p=0.05)	1.630	0.588	0.146

plant and siliqua/plant might be due to the fact that mustard is a long duration crop and being indeterminate in nature and the favorable effect of calcium and sulfur in improving nutritional environment extended over a long duration. The findings of the present study are similar to the results obtained by several workers [11, 12]. Use of different doses of sulfur increased successively in cell multiplication, cell elongation and cell expansion throughout the entire period of crop. The findings were in accordance with respect of Mishra et al. [13].

Data on days to 50% flowering, secondary branches/plant (no.) and 1,000 seed weight (g) as affected by application of calcium and sulfur levels are presented in Table 3. Maximum number of secondary branches/plant (no.) and 1,000 seed weight (g) was recorded with application of calcium and sulfur @ 25 kg^{-1} it was significantly superior over remaining doses. Similar results have been reported by Yadav et al. [14].

The grain and stalk yield of mustard were influenced significantly due to the application of calcium and sulfur (Table 4). The significantly higher grain yield 18.7 q/ha was obtained with the application of Ca @ 25 kg + S @ 25 kg ha^{-1} but it was minimum in control plots (7.5 q/ha). However, the highest stalk yield (44.7 q/ha) was recorded with same fertilizer combinations, while lowest was attained with control plots (20.61 q/ha). Response of calcium and sulfur in protein content and oil percentage of mustard crops significantly increased over control. Highest protein content and oil percentage (26.37 and 41.85) was recorded with the application of Ca @ 25 kg + kg S @ 25 ha^{-1}. As for protein and oil content (%), the data of Table 4 also revealed that under combination of Ca and S with recommended dose of NPK, the protein and oil content was the highest, while it was significantly decreased in control plots (only use of nitrogen @ 50 kg/ha and phosphorus @ 50 kg/ha). Increase in oil content by sulfur application might be attributed to involvement of sulfur in the biosynthesis of oil. Sulfur is involved in the formation of glucosides and glucosinolates and sulphydril-linkage and activation of enzymes, which aid in biochemical reaction within the plant. The higher oil yield by sulfur application was obviously because of higher seed yield and oil content. Beneficial role of S increase oil content have also been reported in mustard by Jaiswal

Table 4. Effect of different treatments on grain, stalk yield, protein and oil content of mustard.

Treatments	Grain yield (gm^{-2})	Grain yield (q ha^{-1})	Stalk yield (gm^{-2})	Stalk yield (q ha^{-1})	Protein content (%)	Oil content (%)
Control (farmers practices)	66.5	7.5	197.61	20.61	19.49	35.32
25 kg Ca ha^{-1}	82.4	8.5	285.87	27.5	21.93	38.42
25 kg S ha^{-1}	131.7	15.1	318.27	32.9	24.75	39.21
25 kg Ca + 25 kg S ha^{-1}	171.5	18.7	439.12	44.7	26.37	41.85
20 kg Ca + 20 kg S ha^{-1}	146.6	16.4	388.51	39.6	25.73	40.13
SEm ±	0.11	0.22	0.51	0.49	0.024	0.014
CD (p=0.05)	0.34	0.68	1.58	1.53	0.076	0.043

et al. [15]. The positive influence of sulfur and boron in improving yield and yield attributes of sunflower was also reported by Shekhawat and Shivay [16].

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