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Effect of different levels and sources of sulphur on growth, yield attributes and nutrient removal by mustard (*Brassica juncea* L.)

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Abstract
A field experiment was carried out at Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) during Rabi season 2015-16 to study the effect of different levels and sources of sulphur on growth, yield attributes and nutrient removal by mustard *(Brassica juncea L.)*. The trial was laid out in Randomized Block Design. Seven treatments viz. RDF (NPK: 120:60:60 kg ha-1), RDF + 20 kg S ha-1 through SSP, RDF + 40 kg S ha-1 through SSP, RDF+ 20kg S ha-1 through Sulphur Bentonite, RDF+ 40kg S ha-1 through Sulphur Bentonite, RDF+ 20kg S ha-1 through Phosphogypsum, RDF+ 40kg S ha-1 through phosphogypsum with three replications on silt loam soils. The growth characters like plant height, number of branches were significantly higher under R.D.F + 40 kg S ha-1 through SSP as compared to other treatments. The yield components like number of siliqua plant-1, length of siliqua (cm), grain yield (q ha-1) and stover yield (q ha-1) were significantly higher under R.D.F + 40 kg S ha-1 through SSP. N, P, K & S content and uptake in crop were obtained higher with R.D.F + 40 kg S ha-1 through SSP which was significantly higher than rest of treatments. Thus, it can be concluded that a dose of R.D.F + 40 kg S ha-1 through SSP may be most suitable nutrient combination for achieving higher yield, better seed quality and economics of mustard.

Keywords: Growth, Uptake and yield components etc.

Introduction

Rapeseed mustard is the second-most important oilseed crop in India, next only to soybean, with almost one-fourth share in both area and production (Jat et al. 2019). It is cultivated in an area of 6.3 million hectares with a production of 8.0 million tonnes yielding 1324 kg ha^{-1}, whereas in Uttar Pradesh, mustard is grown in the area of about 6.79 lakh hectares with an annual production of approximately 9.45 lakh tonnes (DOAC 2017). Oilseeds, the raw material for vegetable oils, occupy a significant position in India's national economy, next to food grains, accounting for about 10 percent of the cultivated area. The requirements for vegetable oil seed have been projected to be around 34 million tonnes by 2020AD. Out of which, 14 million tonnes is to be contributed by rapeseed-mustard to meet the annual domestic demand based on present level of consumption of fats and oils (8.5 kg $Capita^{-1}$ $year^{-1}$). India has got one of the important place among the leading oilseed producing countries of the world. Oilseed ranks the second largest agriculture commodity after cereals. Mustard is the second most important edible oil seed crop after groundnut. It plays an important role in the oil seed economy of the country. India occupies third position in rapeseed and mustard production in world after Canada and China. There exists a huge gap between the global productivity (20.47 q ha−1) and India's productivity (13.24 q ha−1) which need to be bridged with the expansion of area under high yielding varieties (hybrids) due to their improved genetic potential (Rana, Singh, and Parihar 2019) [4]. Further, the yield potential of any crop is best utilized in the presence of optimum fertilization and irrigation. In terms of nutritional requirement, Sulphur (S) plays a major role in determining yield, quality and resistance of mustard toward various stress factors. The multi functionality of Sulphur is also evident in chlorophyll synthesis, seed protein, enzymatic and vitamin components which is sine qua non for superior nutritional and market quality oilseed production. Among secondary and micronutrients, the deficiency of sulphur restricts the optimum production of oil seed crops. Sulphur is now recognized as the major plant nutrient after, nitrogen, phosphorus and potassium. The oil seed crops are the most affected as their requirement of sulphur is higher than other crops. Sulphur, as forth major nutrient with nitrogen, phosphorus and potassium, is a constituent of three sulphur containing amino acids (cysteine, cysteine and methionine), which are the building blocks of protein and about 90% of plant S is present in these amino acids. Sulphur improves protein and oil content in seeds. It is also associated with special metabolism in plant and the structural characteristics of protoplasm. Sulphur deficiency is becoming widespread throughout the world, especially in India. In agricultural system with low sulphur inputs, soil organic matter is a major source of S and the transformations between organic and inorganic S pools are important for the supply of S to the plants. Sulphur fertilizers are most commonly available as either soluble sulphate or elemental forms (S). Elemental S is totally unavailable to plants. Elemental S must be oxidized by soil microbes to SO_4-S before it becomes available to crops. Thus, it takes considerably more time for S to become available, compared to soluble sulphate forms of fertilizer. The rate of conversion from S to plant available SO_4-S mainly depends on the particle size to which the product degrades and the method of application. Therefore, this field experiment was undertaken to assess the effect of different levels and sources of sulphur on growth, yield attributes and nutrient uptake by mustard (*Brassica juncea* L.) in the eastern Uttar Pradesh of India.

Materials and Methods

Site description and soil type

A field experiment was carried out during the Rabi season of 2015–16 at the PCP Instructional Research Farm (26.47˚ N latitude and 82.12˚ E longitude and about 113 meters above the mean sea level) of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The experimental site falls under sub tropical region in Indo-Gangatic plains climate with hot summer and cold winter. Nearly 80 per cent of the total rainfall is received during monsoon season from July to September with a few showers in winter season. The region receive a mean annual precipitation of about 58 mm westerly hot winds start from the month of April and continued till the onset of the monsoon. Weekly mean minimum and maximum temperature during the crop season ranged from 5.2 to 15.4^{0}C and 13.6 to 33.4^{0}C, respectively. The soil of the experimental site was Silt loam in texture with 8.2 pH. The average value of organic carbon, available nitrogen, phosphorus, potassium and Sulphur during the period of experiment were observed as 0.32%, 145.5, 8.78, 188.5 kg ha^{-1} and 15.23 mg kg^{-1} soil, respectively.

Experimental setup

The experiment consisted of 3 replications which were arranged in a Randomized Block Design (RBD). The experiment consisted of 7 treatments combinations namely, RDF (NPK: 120:60:60 kg/h)(T_1), RDF + 20kg S/ha through SSP(T_2), RDF + 40kg S/ha through SSP(T_3), RDF + 20kg S/ha through Sulphur Bentonite(T_4), RDF + 40kg S/ha through Sulphur Bentonite(T_5), RDF + 20kg S/ha through Phosphogypsum (T_6), RDF + 40kg S/ha through phosphogypsum (T_7).

Cultivation practices: Land preparation was started after harvesting of *Kharif* crop. One ploughing was done by disc plough followed by two ploughing by tractor drawn cultivator. The planking was done invariably after each ploughing to get the fine seed bed. Layout was carefully done as per technical programme of the experiment. On the basis of the gross plot size, half dose of the nitrogen and the required quantity of SSP, phosphogypsum and sulphur bentonite on the basis of sulphur content were applied in the treatments at the time of final land preparation and mixed in the soil. Remaining half dose of the nitrogen was applied at first irrigation of mustard crop. Sulphur was supplied through SSP, phosphogypsum and sulphur bentonite as per treatments in each plots. Recommended (120:60:60) dose of NPK was also applied in each plots. Nitrogen was supplied through Urea, Phosphorus through the DAP and Potash was supplied through MOP. Mustard seeds were sown in line at the distance as per treatments with the help of seed drill machine. The seed rate was used 6 kg ha^{-1}.

Observation of parameters

Different agronomic traits and yield constituents, viz., plant height (cm), number of primary and secondary branches, number of siliqua plant−1, siliquae length(cm), were recorded as per standard procedure at harvest. Nitrogen, phosphorus, potash & sulphur content in seed and stover was determined separately and multiplied with their respective yield values under each treatment to obtained removal of nutrient by crop at harvest.

Analysis of data

The experimental data obtained during the course of study was subjected to statistical analysis by applying the technique of Analysis of Variance (ANOVA) prescribed for “Randomized Block Design (RBD)” to test the significance of the overall differences among the treatments. By the ‘F’ test conclusion was drawn at 5 per cent probability level. When ‘F’ value in the analysis of variance table was found to be significant, the critical differences (CD) was computed to test the significance of the difference between two treatments (Fisher and Yates 1963).

If the variance ratio was significant at 5 percent level of significance critical difference (C.D.) was calculated with the help of following formula:

$$SEm\pm = \sqrt{\frac{\text{Error vari ance VE}}{r}}$$

CD = S.Em x $\sqrt{2}$ x t value at 5% d.f.

Results and Discussion

Growth

1. Plant height (cm)

There was a consistent increase in height of plants with the advancement in age. The increase in height of plant was rapid up to 90 day of sowing and thereafter, the growth of crop was slow. The perusal of data indicated that among various levels and sources of sulphur, the maximum plant height was recorded significantly at 100% recommended dose of fertilizers (RDF) along with 40 kg sulphur through SSP, which were at par with 100% RDF along with 40 kg sulphur through sulphur bentonite and 100% RDF along with 40 kg sulphur through phosphogypsum at all the growth stages of plant. The minimum plant height was obtained at 100% RDF (control). Sulphur application significantly increased the plant height over control at all the growth stages. The data clearly indicated that plant height significantly increased with increasing levels of sulphur from 0 to 40 kg ha^{-1}. The maximum plant height was recorded at 40kg sulphur ha^{-1}. This may be ascribed due to better nutritional environmental for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body, which ultimately increased the plant height. Improvement in concentration of S in particular and other nutrients in plant due to adequate supply of S seems to have resulted in vigorous vegetative as well as reproductive growth of crop as reflected through increase in growth attributes (Meena *et al*. 2013) [3].

Table 1: Plant height (cm) of mustard (*Brassica juncea* L.) as influenced by different levels and sources of sulphurat successive growth stages

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1–RDF (NPK: 120:60:60 kg ha^{-1})	10.45	60.45	150.20	154.40
T_2-RDF+20kg S ha^{-1} through SSP	14.90	68.84	157.60	162.40
T_3-RDF+40kg S ha^{-1} through SSP	15.20	70.20	168.45	173.95
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	13.50	64.45	156.60	161.05
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	14.60	66.60	167.92	172.82
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	12.80	62.28	153.42	157.92
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	14.20	62.84	167.82	172.65
S.Em±	1.07	0.57	0.58	1.08
CD (P=0.05)	NS	1.75	1.79	3.34

2. Number of branches plant^{-1}

The number of branches plant^{-1} increased significantly with successive increase in the levels of sulphur up to 40 kg ha^{-1}. The maximum number of branches were recorded at 40 kg S ha^{-1} through SSP (10.75, 11.35 and 11.43 branches per plant) at 60, 90 DAS and at harvest stages, which was significantly superior over 0 and 20 kg S ha^{-1} respectively. The minimum branches was recorded under control treatment (6.80, 8.19 and 8.43branches per plant), respectively at 60, 90 DAS and at harvest stages. This might be due to easy available of sulphate ions to plants released through SSP. As SSP is also a good source of calcium. So, sulphur enhances the cell multiplication, elongation and expansion which also imparts more chlorophyll synthesis.

This was probably due to adequate nutrient supply to the crop, which were directly involved in better absorption of applied nutrients and cell multiplication as well as expansion of deep green colour of leaves due to better chlorophyll synthesis. The increase in number of branches might be due to the role of B in cell division, tissue differentiation, carbohydrate metabolism and maintenance of conducting tissue with regulatory effect on other element (Yadav et al. 2013) [5].

Table 2: Effect of different levels and sources of sulphur on number of branches plant^{-1} at different growth stages

Treatments	Number of branches plant^{-1}			
	30DAS	60DAS	90DAS	At harvest
T_1–RDF (NPK: 120:60:60 kg ha^{-1})	2.40	6.80	8.19	8.43
T_2-RDF+20kg S ha^{1} through SSP	2.70	8.12	9.86	9.92
T_3-RDF+40kg S ha^{-1} through SSP	2.80	10.75	11.35	11.43
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	2.52	8.45	9.25	9.45
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	2.60	9.53	11.23	11.39
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	2.50	8.35	9.02	9.10
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	2.58	9.31	11.20	11.34
S.Em±	0.20	0.47	0.49	0.58
CD (P=0.05)	NS	1.45	1.52	1.79

Yield attributes

1. Number of siliqua plant^{-1}: The number of siliqua per plant increased significantly with increasing levels of sulphur (Table 3). The maximum number of siliqua (305.00) was recorded with 100% RDF + 40 kg S ha^{-1} through SSP level, being at par with 100% RDF+40 kg S ha^{-1} through sulphurbentonite and 100% RDF+40 kg S ha^{-1} through phosphogypsum, which was significantly superior over rest of the treatments. The minimum number of siliqua (217.75) was recorded with 100% RDF (control).

2. Length of siliquae

The length of siliquae increased significantly with increasing levels of sulphur up to 40 kg S ha^{-1}, (Table 3) the highest length of siliquae of 6.04cm was recorded with 100% RDF + 40 kg S ha^{-1} through SSP level, being at par with 100% RDF+40 kg S ha^{-1} through sulphur bentonite and 100% RDF+40 kg S ha^{-1} through phosphogypsum, which was significantly superior over rest of the treatments and minimum in the control (5.04 cm).

Table 3: Effect of different levels and sources of sulphur on number of siliqua plant^{-1} and length of siliquae

Treatments	No. of siliqua plant^{-1}	length of siliquae (cm)
T_1–RDF (NPK: 120:60:60 kg ha^{-1})	217.75	5.04
T_2-RDF+20kg S ha^{1} through SSP	242.36	5.45
T_3-RDF+40kg S ha^{-1} through SSP	305.00	6.04
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	235.18	5.28
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	299.64	5.96
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	225.75	5.15
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	298.72	5.84
S.Em±	2.69	0.13
CD (P=0.05)	8.30	0.39

Nutrients uptake

1. Nitrogen uptake by grain and stover

Different levels and sources of sulphur affected significantly uptake of N ingrain and stover by mustard.

The maximum nitrogen uptake by grain and stover was found with the application of 40 kg S ha^{-1} through SSP (59.04 and 35.10 kg ha^{1}), being at par with 100% RDF+ 40 kg S ha^{-1} through sulphur bentonite (47.65 and 28.27kg ha^{1}) and 100% RDF + 40 kg S ha^{-1} through phosphogypsum (52.39 and 30.97kg ha^{1}), which was significantly superior over rest of the treatments (Table 4). Uptake of nitrogen through, grain and stover were increased significantly with increasing levels and sources of sulphur up to 40 kg S ha^{-1}. Various levels and sources of sulphur showed significant effect on nitrogen uptake by mustard. The highest nitrogen uptake by grain and stover was found in 40 kg S ha^{-1} (59.04 and 35.10 kg ha^{-1}) and Minimum nitrogen uptake by grain and stover was found under control plot (41.55 and 24.64 kg ha^{-1}).

2. Phosphorus uptake by grain and stover

Mustard sown with 100% RDF+40 kg S ha^{-1} through SSP significantly depleted the maximum amount of phosphorus *i.e.* 7.55 kg ha^{-1} followed by 6.76, 6.07 kg ha^{-1}through sulphur bentonite and phosphogypsum, respectively in grain. Significantly highest uptake of P through stover was recorded with 100% RDF+40 kg S ha^{-1} through SSP i.e. 10.53 kg ha^{-1} as compared to rest levels and sources of sulphur. The uptake of P through stover under different levels of fertility ranged from 6.38 to 10.53kg ha^{-1}. Increasing levels and sources of sulphur up to 40 kg S ha^{-1} increased significantly the uptake of phosphorus through grain and stover. The highest uptake of P was recorded at 40 kg S ha^{-1} through SSP (7.55 kg ha^{-1}) in grain, and the lowest was recorded under control treatment (4.37 kg ha^{-1}). Similarly, the uptake of phosphorus was increased with increasing supply of sulphur up to 40 kg S ha^{-1} through SSP. The highest uptake of P in stover i.e. 10.53 kg ha^{-1} was recorded with sowing at 40 kg S ha^{-1}through SSP and the lowest uptake of P, 6.38 kg ha^{-1} was recorded with sowing of mustard without sulphur (control).

3. Potassium uptake by grain and stover

It is evident that crop sown with 100% RDF +40 kg S ha^{-1} through SSP depleted significantly the highest amount of K (13.16 and 96.52 kg ha^{-1}) through grain and stover, respectively. However, the lowest depletion of potassium through grain and stover was registered with sowing at 100% recommended dose of fertilizer. The data presented in Table 5 revealed that increasing levels of sulphur increased the uptake of K through grain and stover.

Table 4: Effect of different levels and sources of sulphur on nitrogen and phosphorus uptake by crop

Treatments	N uptake		P uptake		K uptake		S uptake	
	by grain	by stover	by grain	by stover	by grain	by stover	by grain	by stover
T_1–RDF (NPK: 120:60:60 kg ha^{-1})	41.55	24.64	4.37	6.38	8.74	68.46	8.74	9.12
T_2-RDF+20kg S ha^{1} through SSP	49.83	30.15	5.53	8.61	10.73	83.99	11.07	13.46
T_3-RDF+40kg S ha^{-1} through SSP	59.04	35.10	7.55	10.53	13.16	96.52	13.35	17.55
T_4- RDF+ 20kg S ha^{-1} through Sulphur Bentonite	47.65	28.27	5.22	8.61	10.11	82.14	10.60	13.33
T_5- RDF+ 40kg S ha^{-1} through Sulphur Bentonite	55.41	33.14	6.76	10.35	12.07	91.01	12.62	15.73
T_6-RDF+ 20kg S ha^{-1} through Phosphogypsum	46.09	28.41	4.91	7.75	9.82	78.53	10.13	12.40
T_7- RDF+ 40kg S ha^{-1} through phosphogypsum	52.39	30.97	6.07	9.23	11.27	86.40	11.62	14.67
S.Em$\pm$	2.17	1.41	0.54	0.43	0.67	3.34	0.56	0.95
CD (P=0.05)	6.68	4.33	1.66	1.47	2.06	10.16	1.79	2.91

4. Sulphur uptake by grain and stover:

Different levels and sources of sulphur affected significantly uptake of sulphur through grain and stover. It ranged from 8.74 to 13.35 kg ha^{-1}, in grain and from 9.12 to 17.55 kg ha^{-1}instover. It is inferred that uptake of S of Indian mustard increased significantly with increasing rates of sulphur up to 40 kg ha^{-1}.Crop sown with 40 kg S ha^{-1}through SSP showed the highest uptake of sulphur in grain (13.35kg ha^{-1}) and (17.55 kg ha^{-1}) in stover. The uptake of sulphur under different levels and sources of sulphur was ranged from 8.74 to 13.35 kg ha^{-1} in grain and9.12 to 17.55 kg ha^{-1} in stover.

Conclusion

Based on experiment, it may be safely concluded that the plant height increased with the advancement in age of plants upto harvesting stage. On the basis of the study conducted during *rabi* season 2015-16, to assess the effect of various levels and sources of sulphur application on mustard, uptake of N P K and S was significantly superior with application of RDF + 40 kg S ha^{-1} through SSP but there was no significant difference among the treatments for N P K and S content in the mustard crop. Increasing application of sulfur brought significant improvement in growth traits and yield attributes in comparison to no sulfur application during experimentation. Overall, application of 40 kg S through SSP with RDF in 'NDR-8501′ variety of mustard greatly enhanced the number of siliqua plant^{-1}, siliquae length, as also evident through NDR-8501.

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