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Manoj Kumar Singh
Research Scholar, Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh, India

Shrish Kumar Singh
Professor & Head, Department of Agronomy, Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh, India

Chandra Prakash Singh
Assistant Professor, Department of Agronomy, Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh, India

Adyant Kumar
Assistant Professor, cum Junior Scientist, Department of Agronomy, Tilka Manjhi Agriculture College (Birsa Agricultural University, Ranchi), Punsiya, Godda, Jharkhand, India

Corresponding Author:
Manoj Kumar Singh
Research Scholar, Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh, India

Evaluation of varying levels of sulphur and zinc on mustard [*Brassica juncea* (L.) Czern & Coss] yield, nutrient uptake and quality

Manoj Kumar Singh, Shrish Kumar Singh, Chandra Prakash Singh and Adyant Kumar

Abstract
This study was conducted in factorial randomized block design with three replications during 2019-20 and 2020-21 for identify the best level of sulphur and zinc to improve the yield, nutrient uptake and quality of mustard. The treatments of experiment were four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) and four levels of zinc (0, 5, 10 and 15 kg Zn ha^{-1}). The result indicated that application of sulphur and zinc in rapeseed significantly affected the yield and quality of mustard. The application of 60 kg S ha^{-1} was found to be best treatments regarding yield and qualitative characters of mustard, and was followed by 60 kg S ha^{-1} whereas in zinc levels, 15 kg Zn ha^{-1} was found highest yield and qualitative parameters with 10 kg Zn ha^{-1}. Thus, the application of sulphur and zinc improved the productivity and quality of mustard produce of Uttar Pradesh region of India.

Keywords: Nutrient management, mustard, growth, yield, oil yield, nutrient uptake

Introduction
The self-sufficiency in oilseeds attained through “Yellow Revolution” during early 1990’s, could not be sustained beyond a short period. Oilseed crops play an important role in human and animal nutrition for maintaining the normal health. The daily requirement of oil has been estimated to be 55 g of edible oil or 110 g seed (assuming 50% extractability) for human diet (Mukherjee, 2010) [8]. In the world, the area and production of rapeseed and mustard crops is the highest in India (Chauhan *et al*., 2020) [3]. India Rapeseed and mustard belong to family Cruciferae, which is grown in northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*), Brown sarson (*Brassica campestris* var. *brown sarson*), Yellow sarson (*Brassica campestris* var. *yellow sarson*), Toria (*Brassica campestris* var. *toria*) and Taramira (*Eruca sativa*) along with non-traditional species like Gobhi sarson (*Brassica napus*), White mustard (*Brassica* alba) and Ethiopian mustard (*Brassica carinata*). The oil content in mustard seeds varies from 37-49 percent (Bhowmik *et al*., 2014) [2]; the seeds are highly nutritive containing 38-57% erucic acid, and 27% oleic acid.
Sulphur and zinc are most vital nutrients for growth and development oil seeds. Sulphur is considered to be the fourth important essential nutrient after nitrogen, phosphorus and potassium for the plant growth. It is essential for synthesis of amino acids, proteins, oils, 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 sulphur which are the building blocks of proteins. About 90% of sulphur is present in these amino acids. Sulphur 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 sulphur is, therefore, very much crucial for oilseed crops. Sulphur is also a constituent of vitamins, biotin and thiamine (B_1), and also of iron sulphur proteins called ferrodoxins (Scherer *et al*., 2008) [13]. Mustard has highest requirement of sulphur with optimum level ranging from 20 to 60 kg S ha^{-1} depending of the soil S-status and yield potential (Sarmah and Debnath, 1999) [12].
The importance of micronutrients application in increasing crop production has been recognized in India, but the work has been mostly confined to fruit trees and vegetable crops with little attention to field crops in the past. Application of micronutrients like zinc, manganese, boron and molybdenum had increased yield, oil content, protein content and dry matter accumulation in groundnut and mustard (Arabhanvi *et al*., 2015) [1].

Zn-deficiency usually results in severe yield losses and in acute cases lead to the death of the crop plant (Singh, 2000) [19]. Kutuk *et al.* (2000) [6] also suggested that the application of Zn has become necessary for improved crop yields.

Materials and Methods

A study was conducted during *Rabi* season of two consecutive years 2019-20 and 2020-21 at Research Farm of Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh (25.46° N latitude, 82.44° E longitude and at an altitude of 78.00 m above msl) under rainfed condition. The soil of the study area was sandy clay loam in texture having pH 7.90, low in organic carbon (0.40%), available N (196.75 kg ha^{-1}), available P_2O_5 (11.86 kg ha^{-1}), available K_2O (105.48 kg ha^{-1}), available S (8.39 kg ha^{-1}) and available Zn (0.47 ppm). The rainfall received during crop season was 51.10 and 49.80 mm in 2019-20 and 2020-21, respectively. The experiment was laid out in factorial randomized block design having 16 treatment combinations having four levels of S (0, 20, 40 and 60 kg S ha^{-1}) and four levels of zinc (0, 5, 10 and 15 kg Zn ha^{-1}) with three replications. Recommended dose of fertilizer were applied for mustard at the rate of 120 N: 60 P: 40 K kg ha^{-1} through urea, DAP and MOP, respectively. Full dose of P and K were applied at sowing. The treated seeds of mustard (*var*. Pusa Mustard-30) @ 5 kg ha^{-1} were sown and maintain the spacing of 45 cm (row to row). The crop was grown with standard package of practices for the region. The observations on growth and yield attributes were collected at crop harvest. The economics was computed on the basis of prevailing market rates of produce and agro-inputs. Net returns were calculated by subtracting cost of cultivation from gross returns and benefit: cost ratio was worked by dividing the gross returns by the cost of cultivation.

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 (Factorial)” to test the significance of the overall differences among the treatments. By the F-value in the analysis of variance table was drawn at 5 percent probability level and the critical difference (CD) was computed to test the significance of the difference between two treatments (Fisher and Yates, 1963) [4].

Results and Discussion

Effect on Sulphur and Zinc on Yield attributes and Yield of Mustard

The significantly highest mean siliquae per plant and seeds per siliqua (20.61% 4.82% increase over control, respectively) recorded under S_2 and was found statistically at par with S_3 (Table 1). Whereas, S_3 increased the mean seed and stover yield by 34.59% and 34.20% over S_0, respectively, and was followed by S_2 (24.48% and 24.12% over control, respectively) and S_1 (14.59% and 14.46% over control, respectively). Similar results have been obtained from Singh *et al*. (2022) [14] and Younis *et al*. (2020) [18].

Data pertaining to yield attributes and yield as affected by various levels of zinc and stover yield of mustard increased significantly up to Z_3 over control, but the significant increment was not observed in case of test weight and harvest index (Table 1). It was found that Z_3 resulted in 18.32% increase in siliquae per plant, 4.58% increase in seeds per siliqua, 22.85% increase in seed yield, and 22.51% increase in stover yield of mustard over control. These results are in line with the findings of Rimi *et al*. (2020) [10] and Verma *et al*. (2018) [17].

Uptake of Nutrients

The nitrogen, sulphur and zinc uptake by seed and stover significantly affected as the application of different dose of sulphur and zinc. The nutrients uptake by seed and stover significantly higher with S_3 over control; and was found similar to S_2 (Table 2). The total nitrogen, sulphur and zinc uptake by the mustard significantly observed under application of S_3 over S_0; and was at par with S_2. Similar results have been reported by Jat *et al*. (2019) [5] and Ray *et al*. (2015) [9].

Similarly, the beneficial effect of zinc application on nutrients uptake was observed significantly up to Z_3. The nitrogen, sulphur and zinc uptake were recorded 67.25, 17.48 and 72.47 kg ha^{-1} in seed and 33.48, 14.34 and 194.50 kg ha^{-1} in stover with the treatment Z_3, respectively (Table 2). The nutrients uptake by seed, stover and total was obtained least value under Z_0. The similar findings were reported by Sipai *et al*. (2017) [16] and Meena *et al*. (2018) [7]. The interaction effect of different levels of sulphur and zinc was recorded non-significantly on nutrient uptake.

Effect on Sulphur and Zinc on Oil Content (%) and Oil Yield (kg ha^{-1}) of Mustard

A maximum oil yield (792.54 kg ha^{-1}) and oil content (37.19%) were obtained under S_3, which was respectively 11.45% and 49.97% higher than control (Table 3). Sulphur was found more efficient in increasing the oil content of the mustard seeds due to intensive participation of sulphur in glucoside synthesis. The result was in close conformity with the finding of Sahoo *et al*. (2018) [11] and Younis *et al*. (2020) [18].

The oil content was found non-significant under varying levels of zinc, however, higher mean values were observed with Z_3 over Z_0 (Table 3). Whereas, the oil yield varied significantly with the increasing levels of zinc up to 15 kg ha^{-1} (Z_3) (11.30% increase) over Z_0. The result on effect of varying levels of zinc on oil content and oil yield of mustard was in line with the results of Singh *et al*. (2022) [14] and Meena *et al*. (2018) [7].

Table 1: Effect of different levels of sulphur and zinc and their interaction on yield parameters and yields of mustard (mean data of two years)

Treatments	Siliquae per plant	Seeds per siliqua	Test weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
Levels of Sulphur (kg ha^{-1})						
S_0	90.85	12.378	5.28	1583.10	4241.69	37.32
S_1	101.88	12.625	5.32	1814.07	4855.23	37.36
S_2	109.57	12.973	5.33	1970.70	5264.67	37.43
S_3	106.57	12.848	5.33	2130.62	5692.32	37.43
SEm (±)	0.58	0.026	-	1.01	3.95	-
CD (P=0.05)	1.64	0.073	NS	2.84	11.14	NS

Levels of Zinc (kg ha^{-1})						
Z_0	95.97	12.421	5.29	1802.40	4826.57	37.34
Z_1	100.84	12.604	5.31	1848.82	4948.60	37.36
Z_2	104.56	12.850	5.33	1902.46	5082.03	37.43
Z_3	107.49	12.948	5.33	1944.82	5196.70	37.42
SEm (±)	0.58	0.026	-	1.01	3.95	-
CD (P=0.05)	1.64	0.073	NS	2.84	11.14	NS

Treatments – S_0: 0 kg Sulphur ha^{-1}; S_1: 20 kg Sulphur ha^{-1}; S_2: 40 kg Sulphur ha^{-1}; S_3: 60 kg Sulphur ha^{-1}; Z_0: 0 kg Zinc ha^{-1}; Z_1: 5 kg Zinc ha^{-1}; Z_2: 10 kg Zinc ha^{-1}; Z_3: 15 kg Zinc ha^{-1}.

Table 2: Influence of different levels of sulphur and zinc on nitrogen, sulphur and zinc uptake by mustard (mean data of two years)

Treatments	Nitrogen Uptake (kg ha^{-1})			Sulphur Uptake (kg ha^{-1})			Zinc Uptake (g ha^{-1})		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
Levels of Sulphur (kg ha^{-1})									
S_0	51.28	25.06	76.29	11.61	9.73	21.34	53.53	147.07	200.61
S_1	58.34	28.75	87.16	15.00	12.50	27.50	62.52	170.78	233.30
S_2	66.38	32.46	98.92	17.00	14.02	31.01	68.96	186.21	255.17
S_3	68.46	34.30	102.75	17.84	14.55	32.37	70.90	189.25	260.15
SEm (±)	1.31	0.61	2.38	0.30	0.29	0.54	1.07	3.02	4.72
CD (P=0.05)	3.79	1.78	6.89	0.87	0.86	1.58	3.11	8.73	13.65
Levels of Zinc (kg ha^{-1})									
Z_0	52.24	25.82	78.06	12.10	10.08	22.18	50.87	138.93	189.80
Z_1	59.63	28.85	88.63	14.92	12.39	27.31	62.53	170.27	232.80
Z_2	65.31	32.42	97.72	16.94	13.99	30.93	70.04	189.61	259.65
Z_3	67.28	33.48	100.72	17.48	14.34	31.80	72.47	194.50	266.97
SEm (±)	1.31	0.61	2.23	0.30	0.29	0.54	1.07	3.02	4.72
CD (P=0.05)	3.79	1.78	6.89	0.87	0.86	`1.58	3.11	8.73	13.65
S × Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS

Treatments – S_0: 0 kg Sulphur ha^{-1}; S_1: 20 kg Sulphur ha^{-1}; S_2: 40 kg Sulphur ha^{-1}; S_3: 60 kg Sulphur ha^{-1}; Z_0: 0 kg Zinc ha^{-1}; Z_1: 5 kg Zinc ha^{-1}; Z_2: 10 kg Zinc ha^{-1}; Z_3: 15 kg Zinc ha^{-1}.

Table 3: Effect of different levels of sulphur and zinc and their interaction on oil content (%) and oil yield (kg ha^{-1}) of mustard (mean data of two years)

Treatments	Oil Content (%)	Oil yield (kg ha^{-1})
Levels of Sulphur (kg ha^{-1})		
S_0	33.37	528.47
S_1	34.61	628.13
S_2	36.31	715.79
S_3	37.19	792.54
SEm (±)	0.26	4.94
CD (P=0.05)	0.75	13.94
Levels of Zinc (kg ha^{-1})		
Z_0	34.79	629.94
Z_1	35.16	652.91
Z_2	35.63	680.99
Z_3	35.90	701.1
SEm (±)	0.26	4.94
CD (P=0.05)	0.75	13.94

Treatments – S_0: 0 kg Sulphur ha^{-1}; S_1: 20 kg Sulphur ha^{-1}; S_2: 40 kg Sulphur ha^{-1}; S_3: 60 kg Sulphur ha^{-1}; Z_0: 0 kg Zinc ha^{-1}; Z_1: 5 kg Zinc ha^{-1}; Z_2: 10 kg Zinc ha^{-1}; Z_3: 15 kg Zinc ha^{-1}.

Conclusion

This study could be concluded that the most suitable dose of sulphur and zinc nutrients were applied in mustard crop and improved the productivity of mustard as well as oil percentage and oil yield of mustard, which were be obtained with 60 kg S ha^{-1} treated plots and 15 kg Zn ha^{-1}. The application of sulphur @ 60 kg S ha^{-1} and zinc @ 15 kg Zn ha^{-1} were improved the nutrient uptake in mustard crop. So, the study recommended that the secondary and micro nutrient might be enhanced the quality and production of mustard.

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