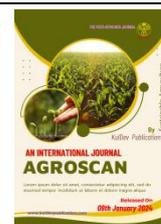


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Research Article

Impact of Zinc and Sulfur Nutrition on Mustard (*Brassica juncea* L.) Growth and Yield Performance and Soil Properties

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ABSTRACT

In order to investigate the impact of zinc and sulfur nutrition on the growth and yield performance of mustard (*Brassica juncea* L.) as well as soil properties, an experiment was conducted during the Rabi season (2019–2020) on sandy loam soil at the research plot of Udai Pratap Autonomous College Varanasi, using the mustard variety VARUNA as a test crop. Table 1 (control), Table 2 (NPK + 8 kg Zn ha⁻¹), Table 3 (NPK + 10 kg Zn ha⁻¹), Table 4 (NPK + 12 kg Zn ha⁻¹), Table 5 (NPK + 40 kg S ha⁻¹), Table 6 (NPK + 40 kg S + 8 kg Zn ha⁻¹), and Table 7 (NPK + 40 kg S + 10 kg Zn ha⁻¹) were the parts of the experiment. When 40 kg S + 10 kg Zn ha⁻¹ was treated, there was a significant increase in the plant's height (141.62 cm), number of branches (80.40 plant⁻¹), number of siliqua seeds (14.87), number of siliqua plants (117.33 cm), seed yield (13.49 q ha⁻¹) and stover production (38.35 q ha⁻¹), and amount of nutrients consumed. Significantly greater nutrient absorption (NPK S) and soil accessible nutrients (NPK S and Zn) were observed with application of 40 kg S + 10 kg Zn ha⁻¹.

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Introduction

The third most important oilseed crop is rapeseed-mustard, after soybean (*Glycine max*) and palm (*Elaeis guineensis*). India contributes significantly to the global rapeseed-mustard sector, producing around 6.7 million tons, third only to China's 11–12 million tons and the EU's 10–13 million tons. The majority of mustard (*Brassica juncea* L.) cultivation in India occurs in the states of Gujarat, Rajasthan, Uttar Pradesh, Haryana, and Madhya Pradesh. In addition, states in south India including Karnataka, Tamil Nadu, and Andhra Pradesh grow it. It is possible to grow this crop in both rainfed and irrigated environments. When nutrients are managed properly, mustard produces more seed and oil by increasing the quantity of siliqua plants per plant, their setting pattern on branches, and other yield-related characteristics. One necessary ingredient in essential amino acids is sulfur. For oilseeds, the quantity of S required to generate one ton of economic yield, or principal output, is generally regarded as 12 kg. The plant system's numerous quality criteria are greatly enhanced by sulfur fertilizer.

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When S was applied together with other nutrients in appropriate levels, Brassica spp. showed a considerable increase in oil content (5–6%) and protein content. One of the first micronutrients to be identified as necessary was zinc. For plants that are diffusely delivered to the plant root surface [1]. Micronutrient zinc deficiency may cause symptoms that can last for the duration of the crop season [2]. Plants lacking in zinc also seem to be stunted [3], and as a consequence, 2 billion people worldwide suffer from zinc deficiency [4]. Zn fertilizer may be added to increase grain yield [1]. Zn produced the greatest stover production (2770 kg ha⁻¹) and the seed yield trend was almost same [5]. Zn fertilizer may be used to increase the seed production. With the aforementioned information in mind, the purpose of this experiment is to assess how soil characteristics and mustard (*Brassica juncea* L.) growth and yield performance are affected by dietary zinc and sulfur.

RESOURCES AND TECHNIQUES

This field study was conducted in the Rabi season (2019–20) in the agricultural form of U. P. Autonomous College, Varanasi, which was built on soil that had been deposited by alluvium. The texture of the soil was sandy clay loam, with a response that was neither alkaline nor mildly saline. Bulk density of 1.42 g cm⁻³, particle density of 2.65 g cm⁻³, pH (1:2.5) of 7.85, EC of 0.21 dS m⁻¹, organic carbon of 0.44%, water holding capacity of 43.5%, available nitrogen of 259.26 kg ha⁻¹, available phosphorus of 12.5 kg ha⁻¹, available potassium of 159.26 kg ha⁻¹, and available carbon were the initial physiochemical properties of the experimental soil. 14.58 kg ha⁻¹ of sulfur. Control (T1), 8 kg Zn ha⁻¹ + RDF (T2), 10 kg Zn ha⁻¹ + RDF (T3), 12 kg Zn ha⁻¹ + RDF (T4), 40 kg S ha⁻¹ + RDF (T5), 40 kg S ha⁻¹ + 8 kg Zn ha⁻¹ + RDF (T6), and 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ + RDF (T7) were the treatments given to the mustard crop. The randomized block design used three duplicates of each treatment.

For mustard, a dosage of 60:30:40 was advised. kg N:P₂O₅:K₂O ha⁻¹. Depending on the treatments, the crop was given varied amounts of Zn and S from inorganic fertilizer. 50% basal, 25% after 45 days after transplanting, and 25% after 60 days were administered as nitrogen from urea. As a basal dressing, single super phosphate, muriate of potash, zinc oxide, and elemental sulfur were used to provide the whole dosage of P, K, Zn, and S at the time of sowing. At 30 DAT and after crop harvest, soil samples were taken from each plots at a depth of 0–15 cm, and they were placed in a plastic bag. A single soil sample from every plot was allowed to air dry before being processed through a 2mm round hole sieve. The samples were then analyzed using the techniques outlined by Walkley and Black method [6], Subbiah and Asija [7], Olsen's et al. [8], Hanway and Heidel [9], for oxidizable organic carbon (1N K₂Cr₂O₇), available N (0.32% alkaline KMnO₄ oxidizable), P (0.5 M NaHCO₃ extractable), K (1N neutral ammonium acetate extractable), S (0.15% CaCl₂), and S (Turbidimetric). The pH of the soil was measured in a 2:1 soil solution using a conductivity bridge and a glass electrode in a digital pH meter to measure the electrical conductivity of the soil in the supernatant liquid [10]. It was determined what the bulk density of undisturbed materials was using metal cores measuring 4.2 cm in diameter and 5.8 cm in height [11].

The mustard variety VARUNA was chosen to serve as the test crop. In order to calculate the mean plant height at 30 and 120 days after sowing, five randomly marked plants were placed in each replicated plot. The plants' height was measured from the base to the tip of the uppermost fully grown and stretched leaf prior to the emergence of siliqua and from the base to the tip of siliqua after its emergence. Following grain harvesting and threshing, the grain's weight was noted. Grain yield was subtracted from biological yield to determine the straw yield. Also noted were the quantity of oil in seeds and the number of branches and leaves per plant. After being harvested, plant samples (leaf and grain) were dried in the shade and then dehydrated for 12 hours at 70°C in an oven. Following that, the samples were ground, and the total P, K, and S content in the plant samples was ascertained by digesting them with a di-acid (HNO₃:HClO₄ in a 10:4) combination [10], whilst the chromic acid technique [12] was used to evaluate the Zn and N contents, respectively. The calculation of Zn and NPKS plant absorption included multiplying the yield by the corresponding nutrient concentration. Statistical analysis was performed on the field and laboratory data using the conventional randomized block design approach [13]. The significance between treatment means was ascertained by calculating the critical difference and standard error of the mean.

END RESULTS AND TALK

Zinc and sulfur's effects on development and yield characteristics

The quantity of zinc and sulfur rose together with the plant's height and branch count (plant 1). The treatment of 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ (T7) produced the greatest value of both parameters and was noticeably better than the other dosages of zinc and sulfur at both development stages (Table 1). With the application of 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ (T7), the maximum plant height and number of branches plant⁻¹ were observed. This may be because of balanced nutrition, the production of indole acetic acid (IAA), and the buildup of chlorophyll content [14].

Table 1 Effect of Sulphur and Zn application on plant height (cm) and number of branches plant⁻¹

Treatment	Plant height (cm)			Number of branches plant ⁻¹	
	Days after sowing			Days after sowing	
	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS
T ₁	19.97	49.86	101.66	10.77	41.40
T ₂	20.15	51.54	105.67	12.78	42.78
T ₃	21.26	52.56	111.68	13.80	47.79
T ₄	21.54	55.80	116.80	14.58	58.59
T ₅	21.68	62.26	128.89	15.39	60.18
T ₆	21.80	63.60	131.87	16.20	69.60
T ₇	21.98	67.06	141.62	18.00	80.40
SEm±	0.1598	0.6898	0.1206	0.0811	0.3065
CD (5%)	0.4924	2.1256	0.3717	0.2498	0.9444

Table 2 Effect of Sulphur and Zn application on number of siliqua plant⁻¹, number of grain siliqua⁻¹, grain and stover yield (q ha⁻¹) of mustard crop

Treatment	Number of siliqua plant ⁻¹	Number of grains siliqua ⁻¹	Grain yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)
T ₁	50.23	6.21	4.10	19.87
T ₂	65.86	8.11	6.95	21.95
T ₃	79.13	9.48	7.67	24.55
T ₄	100.13	10.39	9.40	26.10
T ₅	109.20	11.56	10.95	28.60
T ₆	113.86	13.22	12.60	32.87
T ₇	117.33	14.87	13.49	38.35
SEm±	2.2884	0.3183	0.5595	0.6799
CD (5%)	7.0512	0.9808	1.7240	2.0951

Grain size grew dramatically when zinc and sulfur levels rose to 40 kg S ha⁻¹ and 10 kg Zn ha⁻¹, respectively. The application of 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ produced maximum values (14.87) that were noticeably greater than those of the control and other lower dosages (Table 2) [15–17]. In comparison to the control and other treatments, the application of 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ (T7) produced a statistically equivalent number of siliqua plant⁻¹ (117.33) of mustard, but substantially greater than 40 kg S ha⁻¹ + 8 kg Zn ha⁻¹ + RDF. Because more food is translocated throughout the seed-forming process, siliqua plant⁻¹ and seed siliqua⁻¹ increased at a greater rate when sulfur and zinc levels were higher [18–19]. The use of zinc either by itself or in conjunction with sulfur greatly improved the yield of mustard grains and stover compared to the control (Table 2).

Furthermore, when Zn and S were used together rather of just zinc, the yield was significantly higher. There was a noticeable rise in mustard grain and stover production up to 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ (T7) treatments. The greatest yield (13.49q ha⁻¹) in the current research was noted with 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹, which was 23.24% greater than the control. The biosynthesis of indole acetic acid (IAA), which is regulated by the administration of zinc and sulfur, may be the cause of the yield increase. This would lead to the commencement of development for reproductive parts as well as improved blooming and fruiting [20]. Significantly, the 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ treated region had the highest grain production, which may also be related to higher fertility [21].

Table 3 Effect of Sulphur and Zn application on nutrients (NPK) uptake (kg ha⁻¹) under mustard crop

Treatment	Nutrient uptake (kg ha ⁻¹)		
	N	P	K
T ₁	108.16	7.80	71.50
T ₂	110.61	16.20	74.13
T ₃	112.67	19.40	77.12
T ₄	115.88	23.50	80.07
T ₅	119.10	25.60	83.75
T ₆	122.50	27.40	87.48
T ₇	126.10	28.70	90.44
SEm ±	0.6140	0.4119	0.5592
CD (5%)	1.8919	1.2693	1.7232

Impact of Sulphur and Zn nutrition on nutrients uptake by the mustard crop

Nutrients (NPK) uptake by mustard increased significantly consistently with the addition of S and Zn over control. Effects on various treatment on the consumption of nutrients could be arranged as T₇>T₆>T₅>T₄>T₃>T₂>T₁ (Table 3). Application of 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ + RDF has

recorded significantly higher NPK uptake as compared to other treatments. Data indicated that nutrient uptake followed the trend similar to grain and stover yield of mustard, the nutrient uptake was significantly superior under the conjoint use of Zn and S over alone. The substantial improvement in nutrient uptake indicates the requirement of Sulphur and zinc for the mustard crop [22].

Table 4 Effect of Sulphur and Zn application on soil organic content (%), soil pH and EC (dSm⁻¹) under mustard crop

Treatment	Days after sowing					
	Organic content (%)		Soil pH		EC (dSm ⁻¹)	
	30 DAS	At harvest stage	30 DAS	At harvest stage	30 DAS	At harvest stage
T ₁	0.42	0.40	8.21	8.43	0.48	0.262
T ₂	0.47	0.42	7.58	8.32	0.45	0.49
T ₃	0.49	0.43	7.55	7.60	0.44	0.47
T ₄	0.45	0.44	7.52	7.55	0.42	0.45
T ₅	0.53	0.46	6.65	6.70	0.39	0.43
T ₆	0.54	0.49	6.63	6.67	0.37	0.39
T ₇	0.60	0.51	6.60	6.65	0.36	0.39
SEm±	0.0067	0.0028	0.0944	0.2242	0.0044	0.0160
CD (5%)	0.0205	0.0087	0.2908	0.6907	0.0134	0.0492

Impact of applying zinc and sulfur on soil characteristics during mustard crop

When 40 kg S and 10 kg Zn were applied per hectare, the highest organic carbon content (0.60) was observed. The different treatments may be organized as T₇>T₆>T₅>T₄>T₃>T₂>T₁ (Table 4) based on the amount of organic carbon in the soil. At harvesting, the values of each treatment were recorded at 0.51, 0.49, 0.46, 0.44, 0.43, 0.42, and 0.40%. When zinc and sulfur were combined, the organic carbon content was significantly greater than when zinc was used alone. The findings showed a significant increase in organic carbon above the original value of 0.42 percent recorded at the beginning of the experiment in every treatment except T₁ (Control). The fact that Zn and S treatments stimulate the proliferation and activity of microorganisms may be the reason for the improvement in the status of soil organic carbon. The use of fertilizers promotes better root and shoot development, which may enhance the soil's organic carbon content by contributing biomass [23–24].

Similar to organic carbon, treatment including both zinc and sulfur showed a noticeably greater accessible nitrogen concentration than zinc alone (Table 5). With an application of 40 kilogram S ha⁻¹ + 10 kg Zn ha⁻¹, the maximum accessible N content (340.46 kg ha⁻¹) was recorded. The treatment of zinc and sulfur significantly raised the available nitrogen content compared to the control because the physiochemical parameters of the soil beneath the treated plots improved. The right soil conditions under the application of S and Zn may have aided in the mineralization of soil nitrogen, which increased the amount of nitrogen that was available for use. The 40 kg S ha⁻¹ + 10 kg Zn ha⁻¹ treated plot had significantly greater accessible phosphorus (Table 5) than the other treatments; this difference may be attributed to increased plant residue incorporation [25]. The accessible phosphorus level was found to be substantially higher when Zn and S were applied together than when Zn was applied alone. The emission of sulfuric acid during the oxidation of sulfur was identified as

the cause of the increase in accessible phosphorus content associated with concurrent usage of zinc and sulfur. This helps in causing this acid's solubilizing activity to release native phosphorus [26]. When 40 kg S ha⁻¹ and 10 kilogram Zn ha⁻¹ were applied together, the available K content was significantly greater than with other treatments (Table 5). Along with the rising zinc level, there was an increase in the soil's accessible K content. The findings also showed that the addition of sulfur and zinc increased the soil's accessible potassium concentration relative to control. In addition to the direct addition of K to the soil, a decrease in K fixation and release of K owing to an acid's interaction with clay may be the cause of an increase in accessible K resulting from the addition of zinc and sulfur [27].

The administration of various S and Zn treatments had a considerable impact on the soil's accessible sulfur concentration (Table 5). Additional data showed that the addition of zinc and sulfur caused the soil's accessible S concentration to rise beyond control. The experimental soil's available S content has increased significantly when 40 kilogram S ha⁻¹ + 10 kg Zn ha⁻¹(T7) was applied. the direct addition of zinc and sulfur dosages, which increased the soil's accessible sulfur content in the S treated patch. When sulfur and zinc are used together, the pH and EC of the soil are much lower than when zinc is used alone, indicating an ameliorating impact. When sulfur is administered, sulfuric acid is released during oxidation, neutralizing the salt in the surface soil. This might explain why sulfur-treated plots had lower pH and EC than zinc alone. Reduced soil pH and EC under mustard crop observed because of rising S and Zn levels brought on by acid released during fertilizer-water interaction [28].

Table 5 Effect of Sulphur and Zn application on available NPK and S (kg ha⁻¹) of soil under mustard crop

Treatment	Available nitrogen (kg ha ⁻¹)			Available phosphorus (kg ha ⁻¹)			Available potassium (kg ha ⁻¹)			Available Sulphur (kg ha ⁻¹)		
	30	60	At harvest	30	60	At harvest	30	60	At harvest	30	60	At harvest
	DAS	DAS	stage	DAS	DAS	stage	DAS	DAS	stage	DAS	DAS	stage
T ₁	261.16	245.00	234.79	13.25	12.28	9.87	192.25	182.42	179.63	13.20	10.80	8.24
T ₂	274.28	265.68	249.12	19.75	13.80	11.45	226.32	215.53	186.30	17.68	14.61	10.55
T ₃	308.42	301.62	284.47	23.06	19.25	18.26	238.36	223.32	206.36	22.18	20.18	18.00
T ₄	287.47	275.25	246.30	21.26	20.64	13.25	232.60	225.60	204.72	16.05	14.63	12.43
T ₅	318.46	301.22	288.68	25.74	22.26	19.06	246.55	230.54	221.40	21.90	20.05	19.50
T ₆	336.12	307.82	290.52	27.68	23.42	22.64	247.50	238.46	229.40	24.64	22.59	18.55
T ₇	340.46	319.55	297.34	28.48	24.47	23.55	265.60	245.54	240.23	25.65	23.53	20.22
SEm±	3.5202	1.1572	2.0733	0.3679	0.2844	0.5436	1.3189	2.9663	2.8636	0.5620	0.5933	0.5369
CD (5%)	10.8469	3.5656	6.3886	1.1335	0.8762	1.6750	4.0638	0.1402	8.8237	1.7318	1.8281	1.6545

Conclusion

The application of 40 kg S ha⁻¹ and 10 kg Zn ha⁻¹ in conjunction with RDF improved the growth, yield, absorption of nutrients, and availability of nutrients in mustard crops, according to the study's results. It is clear that applying 40 kilogram S ha⁻¹ and 10 kg Zn ha⁻¹ in addition to RDF will support mustard production in a sustainable manner.

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