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Effect of Zinc and Sulphur on Growth, Yield Attributes and Seed Yield of Indian Mustard [*Brassica juncea* (L). Czern and Coss]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were conducted to study the effect Zinc and Sulphur on growth parameters, yield components and yield of Mustard during *rabi* season of 2021-22 at students instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The experiment consist of

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14 treatments combinations in factorial randomized block design with three replications consisted of 7 fertility levels (including sulphur and zinc) and two variatal factors (i.e. Rohini & Maya). Mustard varieties Rohini & Maya were grown with the recommended agronomic practices. On the basis of results emanated from investigation it can be concluded that among the growth parameters maximum plant height at harvest is 160.6 cm and 161.2 cm, maximum number of primary branches is 8.5 and 8.3 and secondary branches is 14.4 and 14.8 during both the years of experimentation are associated with the treatment T_{14}[Var. Maya with Sulphur @900 ppm]. Similarly, among the yield components and productivity parameters maximum number of siliquae per plant, number of seed siliqua^{-1}, 1000 test wt. (gm), grain yield (q ha^{-1}), stover yield (q ha^{-1}) was also found in the treatment T_{14} [Var. Maya with Sulphur @900 ppm] followed by treatment T_{11} [Var. Maya with $ZnSo_4$ @1500] and treatment T_7 [Var. Rohini with Sulphur @1500].

Keywords: Mustard [Brassica juncea (L). Czern and Coss]; zinc; Sulphur; yield.

1. INTRODUCTION

"Rapeseed and mustard is one of the most important edible oil seed crops of India next to groundnut and soybean. India has 12-15% of the world's area under oilseed but account for less than 6-7 % of world's production to meet the need of about 16% of world population" (FAO, 2011). "India ranked third, both in terms of production and area under rapeseed and mustard in the world with 9.34 mt production and 6.23 m ha of area and having average productivity 1499 kg ha-1" (Directorate of economics and statistics, 2020-21 (DAC&FW). "Rajasthan having first position in terms of area and production accounting for 2.37 m ha & 4.08 mt followed by Uttar Pradesh with around 0.75 m ha & 1.12 mt out of the total rapeseed mustard area and production respectively. In UP Mathura district has the highest area, production and productivity which is 0.053 mha, 0.077 mt and 1453 kg ha-1 respectively" (Directorate of economics and statistics, 2020-21 (DAC&FW).

The plant species *Brassica juncea,* also referred to as Indian mustard or brown mustard, is a member of the *Brassicaceae* family. It is a significant crop that is widely grown around the world for its seeds, leaves, and oil. Annual plants like *Brassica juncea* often reach heights of 1 to 2 metres (3 to 6 feet). It features upright stems with large, lobbed leaves with green to purplish undertones. India and Bangladesh are the two countries in South Asia where *Brassica juncea* is indigenous. Other places with favourable weather conditions, including as portions of Africa, Europe, North America, and Australia, are also where it is grown [1].

The soils in Uttar Pradesh have been found to be deficient in micronutrients. The advent of high yielding crop varieties and intensive cropping systems has made the problem worse. Micronutrient deficits are predicted to worsen as nutrient demands for higher yields rise and plant needs for main nutrients are only partially satisfied. Farmers, extension agents, and researchers have all noted nutritional deficiencies in the soil of Uttar Pradesh. Poor vegetative development, flower and fruit drop, a low harvest index, and low seed production are all associated with a lack of the aforementioned micronutrients. The most important nutrients for the growth and development of oil seeds are sulphur and zinc [2].

"It is widely known how certain micronutrients affect plant metabolism. Zn plays a role in the production of auxins and indole-3-acetic and activates a number of enzymes that are involved in plant metabolism. Sulphur is an essential secondary plant nutrient and fourth most important nutrient in crop production to increase quality and productivity of mustard next to N, P and K. It is an essential constituent of S-containing amino acids and helps in synthesis of cystine (27 % S), cysteine (26 % S) and methionine (21 % S), as about 90 % of sulphur is present in these amino acids" [3]. "Sulphur is an essential component in the formation of chlorophyll, a constituent of vitamins biotine and thiamine (B_1) and iron sulphur proteins called ferredoxins. It also plays a role in activation of various vitamins and enzymes, sulphydryl (SH) linkages, synthesis of oil and protein" (Rathore et al., 2015). "It is also a component of glucosinolate and glycosidase enzyme, which are the source of aroma and pungency in mustard oil. Compared to other crops mustard is more responsive to sulphur. Therefore, adequate sulphur availability is very crucial for its productivity. Studies have confirmed that sulphur fertilizer increases the growth, yield and quality of Indian mustard" [4,5]. "Application of sulphur has a significant effect on oil, fatty acids and glucosinate content in mustard seeds" [6]. Sulphur application also has marked effect on soil properties and is used as soil amendment to improve the availability of other nutrients in soil.

2. MATERIALS AND METHODS

Experimental site: The experiment was conducted during *rabi* season of 2021-22 and 2022-23 at student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The field was well leveled and irrigated by tube well. The farm is situated at main campus of the university, in the west northern part of Kanpur city under sub-tropical zone in v^{th} agroclimatic zone (central plain zone).

Edaphic condition: The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.97 and 7.92 (1:2.5 soil: water suspension method given by Jackson, [7]), electrical conductivity 0.36 and 0.35 dSm^{-1} (1:2.5 soil: water suspension method given by Jackson, [7]), Organic carbon percentage in soil is 0.35 and 0.35 per cent (Walkley and Black's rapid titration method given by Walkley and Black, [8]), with available nitrogen 197.25 and 198.42 kg ha^{-1}(Alkaline permanganate method given by Subbiah and Asija, [9]), available phosphorus as sodium bicarbonate-extractable P was 12.14 and 12.21 kg ha^{-1} (Olsen's calorimetrically method, Olsen et al., 1954) available potassium was 265.15 and 266.68 kg ha^{-1} (Flame photometer method given by Hanwey and Heidel, [10]).

Detail of treatments and design: The 14 treatments combination of nutrient management practices having three each Zinc levels (500, 1000 and 1500 ppm) and Sulphur levels (300, 600, 900 ppm) along with two mustard varieties Rohini & Maya. Experiment was laid out in Factorial Randomized Block Design with three replications.

Crop husbandry: "A pre-sowing irrigation (Paleva) was done in the experimental field with an object to get optimum moisture conditions for attaining good germination. At proper tilth, one ploughing with tractor drawn mould bold plough was done followed by two ploughings by cultivator". [25] Nitrogen @ 120 kg ha^{-1}, Phosphorous @ 60 kg ha^{-1} and potash @ 40 kg ha^{-1} applied uniformly through urea DAP and murate of potash respectively. Zinc and Sulphur were sprayed before flowering as per treatment. The sowing of mustard crop was done using a seed rate of 5 kg ha^{-1} with spacing 45×15 cm spacing and 3-4 cm depth.

Harvesting and threshing: "the crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually" [11].

Grain yield: "After threshing the grain yield from each plot was separately weighed and recorded after converting into quintals per hectare" [11].

Table 1. Detail of the treatment combinations

S. No.	Treatment Details	Symbol
1.	Rohini + Control	V_1T_0
2.	Rohini + ZnSO4@ 500 ppm	V_1T_1
3.	Rohini + ZnSO4@ 1000 ppm	V_1T_2
4.	Rohini + ZnSO4@ 1500 ppm	V_1T_3
5.	Rohini + Sulphur@ 300 ppm	V_1T_4
6.	Rohini + Sulphur@ 600 ppm	V_1T_5
7.	Rohini + Sulphur@ 900 ppm	V_1T_6
8.	Maya + Control	V_2T_0
9.	Maya + ZnSO4@ 500 ppm	V_2T_1
10.	Maya + ZnSO4@ 1000 ppm	V_2T_2
11.	Maya + ZnSO4@ 1500 ppm	V_2T_3
12.	Maya + Sulphur@ 300 ppm	V_2T_4
13.	Maya + Sulphur@ 600 ppm	V_2T_5
14.	Maya + Sulphur@ 900 ppm	V_2T_6

Stover yield: "After subtracting the grain yield per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded" [11].

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez [12] the tested at 5 % level of significance to interpret the significant differences.

3. RESULTS AND DISCUSSION

Growth Parameters: A critical perusal of the data given in Table 2 clearly shows that among the growth parameters of Mustard such as plant height (cm) at harvest, number of primary branches plant^{-1} and number of secondary branches plant^{-1} significantly increase due to the application of Sulphur and Zinc. Growth parameters also increased with lapse of time. Plant height at harvest varied from 124.7-160.9 cm, number of primary branches plant^{-1} varied from 5.4-8.4 and number of secondary branches plant^{-1} varied from 11.1-14.6 on pooled basis. Maximum plant height (161.2 cm) at harvest, number of primary branches plant^{-1} (8.5), and number of secondary branches plant^{-1} (14.8) was associated with the treatment T_{14} [Maya with Sulphur @900 ppm] followed by T_{11} [Var. Maya with $ZnSO_4$ @1500] and T_7 [Var. Rohini with Sulphur @1500] during the second year (2022-23) of experimentation. Minimum plant height (124.5 cm) at harvest, number of primary branches plant^{-1} (5.3) and number of secondary plant^{-1} (11.00) were associated with the treatment T_1 [Rohini + Control] during the first year (2021-22) of experimentation. The interaction between mustard varieties and fertility levels on growth attributes was not statistically significant. The growth parameters of mustard might be increased due to essentiality of sulphur and zinc for growth and developments. The consequences of the current investigation are additionally in concurrence with the investigation of Indira et al. [1]3, Rahangdale [14], Bhalavi et al. [15], Mishra et al. [16], Singh et al. [4].

Yield Components: At a glance over the data given in the Table 3 clearly shows that among the yield attributing characters of mustard such as number of siliqua plant^{-1}, number of seed siliqua^{-1} and test weight (gm) increase due to the application of sulphur and zinc but the increase could not reach up to the level of significance. The number of siliqua plant^{-1}, number of seed siliqua^{-1} and test weight (gm) increased to the magnitude of 226.0 to 316.9, 11.31 to 14.18 and 4.57 to 5.93 respectively, on pooled basis. Maximum number of siliqua plant^{-1} (317.5), number of seed siliqua^{-1} (14.26) and 1000 grain weight (6.02 g) was associated with the treatment T_{14} [Maya with Sulphur @900 ppm] during the second year (2022-23) of experimentation. Minimum number of siliqua plant^{-1} (222.4), number of seed siliqua^{-1} (11.23) and 1000 grain weight (4.50 g) was associated with the treatment T_1 [Rohini + Control] during the first year (2021-22) of experimentation. The results of the present investigation are also in agreement with the findings of Kumar et al. [17], Nandan and Bhatnagar [18] and Pandey et al. [19].

Productivity parameters: It is visualized from the data given in Table 4 clearly indicate that among the productivity parameters viz. grain yield (q ha^{-1}) and stover yield (q ha^{-1}) significantly increase due to the application of sulphur and zinc. Grain yield varied from 18.66 to 23.24 q ha^{-1} and stover yield varied from 41.56 to 53.95 q ha^{-1} on pooled basis. The maximum grain yield (23.48 q ha^{-1}), stover yield (54.1 q ha^{-1}), were associated with the treatment T_{14} [Maya with Sulphur @900 ppm] during the second year (2022-23) of experimentation. The minimum grain yield (18.59 q ha^{-1}) and stover yield (41.43 q ha^{-1}) during the first year (2020-21) of experimentation were associated with the treatment T_1 [Rohini + Control] during the second year (2021-22) of experimentation. The surge in seed and stover yields under adequate nutrients supply might be attributed to mainly to the collective effect of a greater number of plant^{-1}, number seed siliqua^{-1} and higher test weight, which was the result of improved translocation of photosynthates from source to sink ultimately yield is increased. The increase in grain yield under adequate nutrients supply mainly due to more yield attributes ultimately resulted more grain yield. Grain, stover and biological yield of chickpea significantly increased due to sulphur and zinc application over their controls. These results also confirms the findings of Rai et al., [20], Abhilish & Sirothia [21] and Yanthan & Singh [22][23-25].

Table 2. Effect of different treatment combination on growth parameters of Mustard

Treatments	Plant Height (cm) at harvest			Number of primary Branches Plant^{-1}			Number of secondary branches Plant^{-1}		
	2021-22	2022-23	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	124.5	124.9	124.7	5.3	5.4	5.4	11	11.2	11.1
T_2	126.9	127.4	127.2	6	6.2	6.1	11.5	11.9	11.7
T_3	140.2	140.6	140.4	6.9	7.3	7.1	12.2	12.5	12.4
T_4	151.3	151.8	151.6	7.8	8.1	8.0	13.5	13.8	13.7
T_5	133.8	134.7	134.3	6.1	6.4	6.3	11.7	12.1	11.9
T_6	141.9	142.5	142.2	7.1	7.2	7.2	12.6	12.8	12.7
T_7	155.1	155.5	155.3	7.9	8	8.0	13.9	14.2	14.1
T_8	125.7	127.3	126.5	5.5	5.6	5.6	11.1	11.7	11.4
T_9	135.5	134.6	135.1	6.3	6.5	6.4	11.9	12.3	12.1
T_{10}	146.2	146.8	146.5	7.2	7.3	7.3	12.8	13.4	13.1
T_{11}	158.5	159	158.8	8.2	8.5	8.4	14.1	14.5	14.3
T_{12}	140.3	140.8	140.6	6.6	6.9	6.8	12.1	12.6	12.4
T_{13}	148.1	148.6	148.4	7.4	7.5	7.5	13.2	13.7	13.5
T_{14}	160.6	161.2	160.9	8.3	8.5	8.4	14.4	14.8	14.6
S.Ed±	2.415	3.080	2.452	0.163	0.149	0.147	0.347	0.281	0.310
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where, *[T_1 = Rohini + control, T_2 = Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]*

Table 3. Effect of different treatment combinations on yield components of mustard

Treatments	Number of siliqua Plant^{-1}			Number of seed siliqua^{-1}			Test Weight (gm)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	222.4	229.5	226.0	11.23	11.38	11.31	4.50	4.63	4.57
T_2	233.5	241.6	237.6	12.35	12.51	12.43	4.61	4.78	4.70
T_3	259.5	263.4	261.5	13.17	13.27	13.22	4.98	5.1	5.04
T_4	282.1	285.8	284.0	13.65	13.89	13.77	5.54	5.83	5.69
T_5	240.8	244.5	242.7	12.64	12.51	12.58	4.66	4.76	4.71
T_6	264	262.9	263.5	13.21	13.48	13.35	5.10	5.24	5.17
T_7	297.2	299.7	298.5	13.78	13.82	13.80	5.62	5.89	5.76
T_8	225.5	229.2	227.4	11.66	11.56	11.61	4.52	4.92	4.72
T_9	245.6	248.3	247.0	12.85	12.94	12.90	4.75	4.9	4.83
T_{10}	271.8	278.1	275.0	13.32	13.56	13.44	5.14	5.25	5.20
T_{11}	310.5	311.2	310.9	13.95	13.99	13.97	5.76	5.96	5.86
T_{12}	252.4	255.8	254.1	12.98	13.2	13.09	4.85	5.11	4.98
T_{13}	275.3	281.4	278.4	13.44	13.52	13.48	5.32	5.56	5.44
T_{14}	316.2	317.5	316.9	14.1	14.26	14.18	5.83	6.02	5.93
S.Ed±	6.185	5.693	7.389	0.283	0.319	0.289	0.118	0.083	0.095
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where, *[T_1 = Rohini + control, T_2 = Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]*

Table 4. Effect of different treatment combinations on productivity parameters of mustard

Treatments	Grain Yield (q ha^{-1})			Stover Yield (q ha^{-1})		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1	18.59	18.72	18.66	41.43	41.69	41.56
T_2	19.64	19.68	19.66	42.11	42.4	42.26
T_3	20.33	21.12	20.73	46.21	46.89	46.55
T_4	21.97	22.31	22.14	50.34	51.12	50.73
T_5	19.65	19.98	19.82	43.21	43.59	43.40
T_6	20.64	21.15	20.90	47.31	47.56	47.44
T_7	22.15	22.56	22.36	50.65	51.19	50.92
T_8	18.75	18.93	18.84	41.69	42.14	41.92
T_9	19.88	20.41	20.15	44.61	44.89	44.75
T_{10}	21.00	21.56	21.28	48.56	48.75	48.66
T_{11}	22.58	22.93	22.76	52.38	52.67	52.53
T_{12}	20.01	21.06	20.54	45.32	45.83	45.58
T_{13}	21.59	21.82	21.71	49.62	49.98	49.80
T_{14}	23.00	23.48	23.24	53.8	54.1	53.95
S.Ed±	0.296	0.294	0.377	0.638	0.787	0.859
C.D. at 5 %	NS	NS	NS	NS	NS	NS

Where, [T_1 = Rohini + control, T_2 **=** Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]

4. CONCLUSION

The current study demonstrate the benefit of Zinc and Sulphur with recommended N, P and K for achieving higher growth parameters and productivity by mustard crop. Application of Zinc and Sulphur increased yield attributes and yield of mustard crop. Finally it can be concluded that the treatment T_{14} [Maya with Sulphur @900 ppm] is a best option for improving productivity of mustard crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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