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Performance of mustard [*Brassica juncea* (L.) czern & Coss] as affected by various levels of sulphur and zinc

Manoj Kumar Singh, Shrish Kumar Singh, Adyant Kumar and Suresh Kumar Kanojia

Abstract
A field experiment was conducted in factorial randomized block design with three replications during 2019-20 and 2020-21 on mustard *var*. Pusa Mustard-30 at the Research Farm of Tilak Dhari P.G. College, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh. The treatments comprises of four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) in combination with zinc at four levels (0, 5, 10 and 15 kg Zn ha^{-1}) were applied as basal dose. The result showed that application of sulphur in combination with zinc in rapeseed significantly affected the growth, yield and quality parameters of mustard. The application of 60 kg S ha^{-1} + 15 kg Zn ha^{-1} was found to be best treatments regarding growth, yield and quality parameters of mustard, and was followed by 60 kg S ha^{-1} + 10 kg Zn ha^{-1}. The maximum benefit-cost ratio of 2.38 and 2.37 was recorded under both the treatments (application of 60 kg S ha^{-1} and 15 kg Zn ha^{-1} and application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}) during 1st and 2nd year, respectively. Thus, the sulphur nutrition in combination with zinc in mustard crop holds immense importance for obtaining better growth and productivity.

Keywords: Sulphur, zinc, mustard, growth, yield, oil content, oil yield, economics

Introduction
Mustard [*Brassica juncea* (L) Czem and Cross] is important Rabi oilseed crop which belongs to family "Cruciferae". India holds the first position in area and second position in production after China. The Assam, Bihar, Rajasthan, Haryana, Uttar Pradesh, Orissa, Punjab and West Bengal are majorly growing of mustard in India (Sharma *et al.* 2020) [1]. The total area under rapeseed and mustard in India is 6.80 m ha with a production of 9.10 m t and productivity of 1345 kg ha^{-1} in the year 2019-20. However, the area, production and productivity of mustard in Uttar Pradesh during the year 2019-20 was 0.76 m ha, 0.96 m t and 1260 kg ha^{-1}, respectively (Agricultural Statistics at a Glance, 2020) [2].

In the recent years, sulphur (S) deficiency has been aggravated in the soil due to continuous removal by crops and use of high analysis sulphur devoid fertilizers coupled with intensive cropping with high yielding varieties and reduction in use of organic manure and sulphur containing fungicides and insecticides resulted in sulphur deficiency in soils. Sulphur deficiency in the soil can not only reduce grain yield and quality of produce, but also make a sharp impact in agro-based economy (Fismesa *et al.*, 2000) [3]. Recently about 45% districts of our country had shown more than 40% S deficiency. Sulphur is accumulated in plants in low concentrations compared to N, but is an essential element as a constituent of proteins, cysteine-containing peptides such as glutathione, or numerous secondary metabolites. Sulphur is associated with the production of oilseed crops of superior nutritional and market quality. The reports on sulphur deficiency compels that 10-40 per cent yield is reduced due to adverse effect on growth and development of mustard crop (Kumar *et al.*, 2012) [4].

Zinc (Zn) being one of the essential micronutrient, plays significant role in various enzymatic and physiological activities of the plant system. It is also essential for photosynthesis and N-metabolism. It is important for stability of cytoplasmic ribosomes, cell division, dehydrogenase, proteinase and peptidase enzymes; and also helps in the synthesis of protein and carotene. In India, Zn is now considered as fourth most important yield limiting nutrient in agricultural crops. Zinc deficiency in Indian soils is expected to increase from 42% in 1970 to 63% by 2025 due to continuous depletion of soil fertility (Bhatt *et al.*, 2020) [5]. It is, therefore, imperative to find out the suitable doses of S and Zn for improving the productivity of mustard.

Materials and Methods

A field experiment 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 the mean sea level) under rainfed condition. The soil of the experimental plot 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}) in randomized block design with three replications. Nitrogen, P_2O_5 and K_2O were applied for mustard at the rate of 120: 60: 40 kg ha^{-1} through urea, di-ammonium phosphate and muriate of potash, 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 in line at a depth of 2 to 3 cm and the direction of sowing was followed in north-south direction at spacing of 45 cm (R–R). The crop was grown with standard package of practices for the region. The observations on growth and yield characters were collected at the time of harvest. Observations were recorded for different characters and mean values were subjected to pooled analysis. 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.

Results and Discussion

Effect on Sulphur and Zinc on Growth and Yield of Mustard

The varying levels of sulphur had no significant effect on the plant population at 30 DAS of mustard crop, however, the maximum number of plants was observed with the application of 60 kg S ha^{-1}. A significant increase in the plant height, primary and secondary branches, dry matter accumulation, leaf area index, siliquae per plant, siliqua length, seeds per siliqua, seed yield and stover yield were recorded with the increasing levels of sulphur up to 60 kg ha^{-1} at all growth stages during both the years. The significantly highest value of plant height, primary and secondary branches, dry matter accumulation, leaf area index, siliquae per plant, siliqua length, seeds per siliqua, seed yield and stover yield were recorded with the application of 60 kg sulphur ha^{-1} and was followed by the application of 40 kg S ha^{-1} and 20 kg S ha^{-1} (Table 1 & 2). The increase in mustard growth was due to adequate availability of sulphur which resulted in better nutritional environment for plant growth at active vegetative stages as a result of enhancement in multiplication, cell elongation and cell expansion in the plant body which ultimately increased the height and other growth parameters of mustard plant. Thus, sum of total effect of sulphur on growth and development of mustard results in higher seed yield. The similar results were also reported by Rana *et al.* 2020 [6] and Saini *et al.* 2020 [7].

The initial plant population was not affected by the varying levels of zinc, which might be due to the lack of competition for nutrients during the seedling emergence because the demand was fulfilled by nutrients present in the seed itself. A critical examination of data in shows that the maximum yield parameters *viz*. plant height, primary and secondary branches, dry matter accumulation, leaf area index, siliquae per plant, siliqua length, seeds per siliqua, seed yield and stover yield of mustard were recorded with increasing levels of zinc up to 15 kg Zn ha^{-1} at all growth stages during both the years over control and was followed by the application of 10 kg Zn ha^{-1} and 5 kg Zn ha^{-1}, but the significant increment was not observed with the application of 15 kg Zn ha^{-1} in case of dry biomass, siliqua length and seeds per siliqua (Table 1 & 2). The increase in growth of mustard might be due to the fact that zinc plays an important role in the synthesis of tryptophan, a precursor of plant growth hormones and auxins, which promotes the plant growth by the inducement of cell enlargement and cell wall extension as well as increases the nitrogen metabolism which results in the increase in nucleic acid, amides and amino acid contents, causes rapid cell division and is responsible for enhancement of growth characters. These results are in agreement with the findings of Mandal and Sinha, 2004 [8] and Sipai *et al.* (2017) [9]. While, the various levels of zinc did not affect the harvest index of mustard.

Effect on Sulphur and Zinc on Quality Parameters of Mustard

The oil content and oil yield of mustard affected significantly under application of different level of sulphur. The comparison of sulphur fertilized plots with the control plots showed that the sulphur fertilized plots obtained significantly higher oil content (44.10%) than the control plot (41.10%). The oil content was enhanced from 42.80 to 45.20% as the sulphur rate was boosted up to 60 kg ha^{-1}. The oil yield in mustard was shown the similar result during both the years. A significant increase in oil yield seems owing to be cumulative effect of increased oil content and seed yield in response to sulphur application. Sulphur was found more efficient in increasing the oil content of the mustard seeds due to intensive participation of sulphur in glucoside synthesis. These results are in close conformity with the findings of Sahoo *et al.* (2018) [10]. The application of various levels of zinc did not significantly affect the oil content, however, the increase in oil content was observed with increasing the levels of zinc up to 15 kg Zn ha^{-1} during both the years of experimentation. Whereas, maximum oil yield was obtained with 15 kg Zn ha^{-1} and was followed by 10 kg Zn ha^{-1} during both the years. A significant increase in oil yield seems due to obtain significantly higher seed yield under the 15 kg Zn ha^{-1} treatment. Bhadauria *et al.* (2012) [11] also recorded that oil content in mustard was increased by addition of zinc over control and the maximum value of oil yield (7.45 q ha^{-1}) was recorded with the application of 10 kg Zn ha^{-1}.

Economics

A perusal of data presented in table 4 reveals that maximum net return was recorded with the application of 60 kg S ha^{-1} and 15 kg Zn ha^{-1} during both the years of investigation and was followed by the application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}. However, the maximum benefit-cost ratio of 2.38 and 2.37 was recorded under both the treatments (application of 60 kg S ha^{-1} and 15 kg Zn ha^{-1} and application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}) during 1st and 2nd year, respectively. This is due to the increased net return in corresponding to the cost of cultivation under the treatment combinations. Whereas, the low fertility under control treatment (0 kg S ha^{-1} and 0 kg Zn ha^{-1}) resulted in the lowest cost of cultivation, gross return, net return and benefit-cost ratio. The finding is in close conformity with the findings of Sultana *et al.* (2020) [12].

Table 1: Effect of different levels of sulphur and zinc and their interaction on growth parameters of mustard

Treatments	Plant Height (cm) at Harvest		Dry Biomass (g plant^{-1}) at Harvest		Primary Branches Plant^{-1} at 60 DAS		Secondary Branches Plant^{-1} at 60 DAS		LAI at 60 DAS	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Levels of Sulphur (kg ha^{-1})										
0	177.88	177.67	99.07	95.74	7.06	7.05	12.89	12.86	4.32	4.29
20	180.98	180.47	103.17	99.68	7.46	7.44	13.13	13.11	4.67	4.64
40	185.87	185.30	108.39	104.97	7.71	7.70	13.27	13.26	4.92	4.89
60	189.38	189.30	110.83	107.21	7.81	7.78	13.52	13.49	5.11	5.07
S.Em (±)	0.13	0.11	1.10	1.14	0.01	0.01	0.02	0.02	0.01	0.01
CD (P=0.05)	0.38	0.32	3.19	3.28	0.04	0.04	0.06	0.05	0.02	0.02
Levels of Zinc (kg ha^{-1})										
0	180.61	180.33	101.55	98.16	7.43	7.41	13.12	13.07	4.63	4.60
5	183.40	183.22	105.54	101.86	7.47	7.47	13.18	13.16	4.73	4.69
10	184.61	184.23	106.52	103.19	7.55	7.52	13.22	13.21	4.80	4.77
15	185.49	184.95	107.84	104.39	7.60	7.57	13.29	13.28	4.86	4.83
S.Em (±)	0.13	0.11	1.10	1.14	0.01	0.01	0.02	0.02	0.01	0.01
CD (P=0.05)	0.38	0.32	3.19	3.28	0.04	0.04	0.06	0.05	0.02	0.02

Table 2: Effect of different levels of sulphur and zinc and their interaction on yield parameters and yields of mustard

Treatments	Siliquae per plant		Siliqua Length (cm)		Seeds per siliqua		Test weight (g)		Seed yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index (%)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Levels of Sulphur (kg ha^{-1})														
0	90.75	90.94	3.66	3.65	12.39	12.37	5.29	5.27	1587.17	1579.03	4252.8	4230.57	37.32	37.32
20	102.25	101.51	3.73	3.71	12.64	12.61	5.33	5.31	1818.72	1809.43	4867.7	4842.76	37.36	37.36
40	110.18	108.95	3.75	3.75	13.00	12.95	5.34	5.33	1973.56	1967.84	5272.17	5257.17	37.43	37.43
60	107.21	105.93	3.74	3.74	12.88	12.82	5.34	5.32	2134.54	2126.71	5702.64	5681.99	37.43	37.43
S.Em (±)	0.87	0.77	0.01	0.01	0.04	0.03	-	-	1.16	1.64	4.86	6.22	-	-
CD (P=0.05)	2.51	2.22	0.01	0.02	0.11	0.10	NS	NS	3.36	4.74	14.04	17.98	NS	NS
Levels of Zinc (kg ha^{-1})														
0	96.70	95.25	3.69	3.68	12.43	12.42	5.30	5.27	1806.96	1797.84	4838.82	4814.32	37.34	37.34
5	101.19	100.48	3.72	3.70	12.62	12.59	5.32	5.30	1852.96	1844.68	4959.64	4937.55	37.36	37.36
10	104.58	104.54	3.73	3.73	12.88	12.82	5.34	5.32	1906.26	1898.65	5092.18	5071.88	37.43	37.43
15	107.92	107.06	3.74	3.74	12.97	12.93	5.34	5.33	1947.80	1941.83	5204.67	5188.73	37.42	37.42
S.Em (±)	0.87	0.77	0.01	0.01	0.04	0.03	-	-	1.16	1.64	4.86	6.22	-	-
CD (P=0.05)	2.51	2.22	0.01	0.02	0.11	0.10	NS	NS	3.36	4.74	14.04	17.98	NS	NS

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

Treatments	Oil content (%)		Oil yield (kg ha^{-1})	
	2019-20	2020-21	2019-20	2020-21
Levels of Sulphur (kg ha^{-1})				
0	33.36	33.38	529.63	527.31
20	34.55	34.67	628.65	627.62
40	36.25	36.37	715.73	715.85
60	37.13	37.26	792.62	792.47
S.Em (±)	0.35	0.40	6.75	7.22
CD (P=0.05)	1.02	1.14	19.51	20.84
Levels of Zinc (kg ha^{-1})				
0	34.76	34.82	630.96	628.92
5	35.12	35.20	653.67	652.15
10	35.58	35.69	681.25	680.73
15	35.83	35.97	700.75	701.46
S.Em (±)	-	-	6.75	7.22
CD (P=0.05)	NS	NS	19.51	20.84

Table 4: Effect of different levels of sulphur and zinc and their interaction on economics of mustard

Treatments	Net Return (₹ ha^{-1})		B-C Ratio	
	2019-20	2020-21	2019-20	2020-21
S_0Z_0	49754.57	49318.68	1.83	1.81
S_0Z_1	51161.40	50723.04	1.84	1.82
S_0Z_2	52917.98	52653.62	1.86	1.85
S_0Z_3	54504.01	53995.15	1.88	1.86
S_1Z_0	59704.71	59350.80	2.09	2.08
S_1Z_1	61797.83	61373.06	2.12	2.10
S_1Z_2	63111.90	62437.89	2.12	2.10
S_1Z_3	64881.71	64456.48	2.13	2.12
S_2Z_0	66807.38	66197.24	2.23	2.21
S_2Z_1	67961.59	67599.74	2.22	2.21
S_2Z_2	69468.61	69378.32	2.23	2.22
S_2Z_3	70884.65	70793.48	2.23	2.23
S_3Z_0	71669.28	71225.48	2.28	2.27
S_3Z_1	73895.12	73448.58	2.31	2.30
S_3Z_2	77626.95	77118.47	2.38	2.37
S_3Z_3	78856.94	78675.25	2.38	2.37

Conclusion

This study could be concluded that the rate of sulphur application and performance of mustard were shown positive correlation that means the seed and oil yield of mustard could be improved with increasing sulphur application and maximum values were recorded with 60 kg S ha^{-1} treated plots. Similarly, application of zinc is also significantly enhanced mustard growth, seed yield and oil yield but non-significantly improved oil content in seed. During both the years, the highest return per unit cost was obtained under the combination of 60 kg S ha^{-1} and 15 kg Zn ha^{-1} (S_3Z_3) and 60 kg S ha^{-1} and 10 kg Zn ha^{-1} (S_3Z_2).

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