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Effect of sulphur and zinc on yield and uptake of nutrients by mustard (*Brassica spp.* L.) under rainfed condition

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Abstract
Fields experiments were conducted for two years (2013-14 and 2014-15) with mustard (*Brassica spp.* L.) as a test crop under rainfed conditions on sandy loam soils with 5 levels of sulphur (0, 15, 30, 45 and 60 kg ha^{-1}) and 4 levels of zinc (0, 2.5, 5.0 and 7.5 kg ha^{-1}) in Factorial randomized block design with three replications. Seed and stover yield increased significantly up to 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1} application. Application of 30 kg S ha^{-1} increased the seed yield by 51.4 and 28.4% in 2013-14 and 55.3 and 27.5% in 2014-15 over control and 15 kg S ha^{-1}, respectively. Nitrogen, phosphorus, potassium, sulphur and zinc uptake by seed and stover significantly up to 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1} application.

Keywords: mustard, sulphur, uptake, yield, zinc

Introduction
India is the fourth largest oilseed economy in the world. Among the seven edible oilseed crops cultivated in India, rapeseed-mustard (*Brassica juncea* L.) contributes 28.6 per cent in the total production of oilseeds. In India, it is the second most important edible oilseed after groundnut sharing 27.8 per cent in the India's oilseed economy. In terms of acerage, oilseeds occupy 14.1 per cent and rapeseed-mustard alone occupies 3 per cent of the total cropped area in the country. The global production of rapeseed-mustard and its oil is around 38-42 million tone and 12–14 million tone, respectively. India produces around 6.72 million tone of rapeseed-mustard next to China (11-12 million tone) and EU (10–13 million tone) with significant contribution in world rapeseed-mustard industry (Shekhawat *et al.*, 2012).
Presently, rapeseed-mustard [*Brassica juncea* (L.)] is the third most important oilseed crops after soybean and groundnut in India occupying 6.9 million hectare acreage, 8.18 million tonnes production and 1185 kg ha^{-1} productivity (FAI, 2011-12) [5]. The productivity is quite lower than other developed countries mainly due to sub-optimal application of fertilizers and their cultivation on marginal lands under rainfed condition. In recent years sulphur deficiency has been aggravated in the soil due to continuous crop removal and use of sulphur and zinc free high analysis NPK fertilizers. Tandon, (2010) [15] reported that sulphur deficiency trends to affect adversely the growth and yield of oilseed crop, which reduces the crop yield to an extent of 10-30%. The present study was undertaken to evaluate the effect of sulphur and zinc on yield and nutrients uptake by mustard.

Materials and Methods
A field experiment was conducted during the *Rabi* seasons of 2013-14 and 2014-15 at the Rajaula Research Farm, Faculty of Agricultural Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot – Satna, Madhya Pradesh (25° 10' N and 80° 52' E) on sandy loam soil having 0.37% organic carbon, 213.2 kg ha^{-1} available-N, 14.56 kg available P_2O_5 and 219.5 kg K_2O ha^{-1}, with pH 7.8. The available S and Zn was 12.83 and 0.53 mg kg^{-1}. The Treatment consisting of 5 levels of sulphur (0, 15, 30, 45 and 60 kg ha^{-1}) and 4 levels of zinc (0, 2.5, 5.0 and 7.5 kg ha^{-1}) were laid out in Factorial randomized block design with three replications. Treatments were applied as basal dressing through gypsum and zinc oxide as per treatments. Uniform application of 60 kg N, 40 kg P_2O_5 and 20 kg K_2O per ha. Full dose of N, P and K were applied through urea, DAP and muriate of potash at the time of sowing were made. Mustard variety Pusa Tarak was sown in rows at 30 cm apart using 5 kg seed ha^{-1} on second fortnight of October.

The ground seed and stover samples were digested with nitric-perchloric (9:4) di-acid mixture for the analysis of all other elements except N. Nitrogen was determined by KEL PLUS nitrogen estimation system and phosphorus by vanadomolybdate yellow colour method (Jackson 1973). Potassium was estimated flame photometrically. Sulphur was determined by turbidimetric methods of Chesnin and Yien (1951) [2]. Zinc was estimated by double beam Atomic Absorption Spectrophotometer. The uptake of nutrients was calculated as per formula.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient Content (\%) x Yield (kg ha}^{-1})}{100}$$

Results and Discussion
Yield
Data (Table 1) shows that during both the years of experimentations, application of sulphur significantly increased the seed and stover yield of mustard up to 30 kg ha-1. Application of 30 kg S ha-1 increased the seed yield by 51.4 and 28.4% in 2013-14 and 55.3 and 27.5% in 2014-15 over control and 15 kg S ha-1, respectively. With increasing supply of sulphur the process of tissue differentiation from somatic to reproductive, meristematic activity and development of floral primordial might have increased, resulting in more flowers and siliqua, longer siliqua and higher seed yield as reported by Singh and Verma (1989) [14]. Increase in stover yield can be ascribed to the overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the effect of sulphur application. Similar results were reported by Jat and Mehra (2007) [7].

Table 1: Effect of sulphur and zinc levels on seed and stover yield of mustard

Treatments	Seed yield (kg ha-1)			Stover yield (kg ha-1)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Sulphur (kg ha-1)						
0	947.8	969.1	958.5	2674.7	2716.0	2695.4
15	1117.3	1180.3	1148.8	2854.9	3098.8	2976.9
30	1435.2	1504.6	1469.9	3447.5	3515.1	3481.3
45	1476.2	1561.7	1519.0	3586.4	3701.1	3643.8
60	1488.9	1526.2	1507.6	3648.2	3695.7	3671.9
SEm ±	25.4	28.2	19.0	56.3	45.0	36.0
CD (P=0.05)	73.6	81.5	54.3	162.9	130.4	103.1
Zinc (kg ha-1)						
0	1135.1	1176.3	1155.7	3023.2	3001.7	3023.2
2.5	1241.0	1298.8	1269.9	3321.0	3197.0	3321.0
5.0	1397.5	1464.2	1430.9	3533.7	3459.5	3533.7
7.5	1398.8	1454.3	1426.6	3503.5	3517.2	3503.5
SEm ±	22.7	25.2	17.0	40.3	32.2	40.3
CD (P=0.05)	65.8	72.9	48.6	116.6	92.2	116.6

A perusal of data (Table 1) revealed that across the years of experimentation there was a significant increase in seed and stover yield of mustard up to 5.0 kg Zn ha-1. The increase in yield might be due to role of zinc in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting. The findings of present investigations are supported by Singh *et al.* (1996) [13] and Mishra (2001) [10].

Nutrient uptake by mustard
Nitrogen uptake
Nitrogen uptake by mustard seed increased significantly up to the levels of 30 kg S ha-1 but in stover significantly uptake was recorded up to 45 kg S ha-1. this increase in N content is attributed to application of sulphur to plant which is turn provides vigorous root and shoot growth resulting in greater absorption of nitrogen from the soil. This is further supported by the fact that a sulphur deficiency prevents utilizations of nitrogen and also brings about an accumulation of soluble nitrogen within the plants. The increase accumulation of nitrogen in plants thus checks further absorption of nitrogen leading to decrease in N content in plant. (Charlier and Carpentiers, 1956) [1]. The increase N content and its uptake due to sulphur application have also been reported by Sharma *et al.* (1990) [11] in mustard.

The beneficial effect of zinc application on nitrogen uptake was observed significantly up to 5.0 kg Zn ha-1 application. The magnitude of significant increase in nitrogen uptake was 29.9 and 15.2 in seed, 22.5 and 10.9 in stover over control and 2.5 kg Zn ha-1¸ respectively. The beneficial role of zinc in chlorophyll formation, regulating the auxin concentration and its stimulatory effect on most of physiological and metabolic processes of the plant might have helped the plants in enhanced absorption of nutrients from soil. The results are in accordance with the findings of Dwivedi *et al.* (2001) [4].

Phosphorus uptake
Data presented in Table 2 show that the phosphorus uptake in seed and stover increased significantly with increasing levels of sulphur up to 45 kg S ha-1. Application of sulphur not only act as a source of sulphur but it also influenced physical, chemical and biological properties of soil resulting in change like drop in soil pH and release of phosphorus in available form (Kashirad and Bazargani 1991) [8].

Table 2: Effect of sulphur and zinc levels on nutrient uptake by mustard (Pooled data of two years)

Treatments	Nitrogen uptake (kg ha-1)		Phosphorus uptake (kg ha-1)		Potassium uptake (kg ha-1)		Sulphur uptake (kg ha-1)		Zinc uptake (mg kg-1)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Sulphur (kg ha-1)										
0	30.14	14.06	6.54	6.08	5.73	34.33	8.62	11.72	443.7	728.2

15	36.98	16.04	8.03	6.91	7.01	38.99	10.66	13.39	556.8	840.4
30	49.03	19.41	10.59	8.45	9.28	46.90	14.20	16.39	751.9	1020.9
45	50.93	20.34	11.01	8.87	9.67	49.24	14.94	17.24	784.6	1092.7
60	50.77	20.61	10.95	8.99	9.61	49.92	14.91	17.58	780.5	1120.4
SEm ±	0.67	0.21	0.15	0.11	0.13	0.54	0.20	0.20	10.6	14.7
CD (P=0.05)	1.93	0.61	0.43	0.32	0.36	1.55	0.56	0.58	30.3	42.0
Zinc (kg ha^{-1})										
0	36.91	15.81	8.08	7.01	6.98	39.25	10.66	13.15	514.0	740.8
2.5	41.64	17.47	9.04	7.59	7.91	42.42	12.19	14.76	638.9	940.9
5.0	47.95	19.37	10.29	8.81	9.38	46.45	13.89	16.30	749.5	1067.5
7.5	47.78	19.71	10.10	8.52	9.27	47.39	13.91	16.84	751.6	1093.0
SEm ±	0.60	0.19	0.13	0.10	0.11	0.49	0.18	0.18	9.5	13.1
CD (P=0.05)	1.73	0.55	0.38	0.28	0.32	1.39	0.50	0.52	27.1	37.5

It is clear from the data that P uptake increased significantly up to the levels of 5.0 kg Zn ha^{-1}. Thereafter uptake of P was marginally decreased. Phosphorus uptake first increase due to increased in yield but in the higher levels of zinc it decreased due to reduced phosphorus content in the seed and stover. Similar results were also reported by Deo and Khandewal, (2009) [3].

Potassium uptake

Potassium uptake increased significantly with increasing levels of sulphur up to 45 kg S ha^{-1} except in seed where significant increase was obtained only up to 30 kg S ha^{-1}. The increase availability of potassium in root zone coupled with increased metabolic activity at cellular level might have increased the uptake of potassium and their accumulation in vegetative plants parts. Similar findings were reported by Lallu and Saxena (1995) [9].

Further reference to data in table 2 indicates that increase in potassium uptake was found to be significant up to the levels of 5.0 kg Zn ha^{-1}. The magnitude of significant increase in potassium uptake from 5.0 kg Zn ha^{-1} was 34.4 and 18.6 in seed, 18.3 and 9.59 in stover over control and 2.5 kg Zn ha^{-1}¸ respectively.

Sulphur uptake

Sulphur uptake increased significantly with increasing levels of sulphur up to 45 kg S ha^{-1} in both seed and stover. The increase in sulphur uptake might be due to increased concentration of sulphur in soil with the application of sulphur. The higher sulphur concentration in seed and stover resulted in greater uptake of sulphur in plant. The result of present investigation is corroborating with the findings of Jat and Mehra (2007) [7].

The beneficial effect of zinc application on sulphur uptake was observed significantly up to 5.0 kg Zn ha^{-1} application. The magnitude of significant increase in sulphur uptake was 30.3 and 13.9 in seed, 24.0 and 10.4 in stover over control and 2.5 kg Zn ha^{-1}¸ respectively.

Zinc uptake

Under different levels of sulphur zinc uptake was ranged from 443.7 to 784.6 and 728.2 to 1120.4 mg kg^{-1} in seed and stover, respectively. Zinc uptake increased significantly with increasing levels of sulphur up to 45 kg S ha^{-1} in both seed and stover.

It is clear from the data that zinc uptake increased significantly up to the levels of 5.0 kg Zn ha^{-1}. Thereafter uptake of Zn was marginally increased. The increase in zinc uptake might be due to increased concentration of zinc in soil with the application of zinc the higher zinc concentration in seed and stover resulted in greater uptake of zinc in plant. The result of present investigation is corroborating with the findings of Jat and Mehra (2007) [7].

Conclusion

On the basis of the experimental findings, it is concluded that the application of 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1} can be recommended for mustard in Satna district Madhya Pradesh. Application of 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1} gave highest seed and stover yield, content and uptake of nutrients by mustard.

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