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Effect of rate and source of zinc on yield, quality and uptake of nutrients in Indian mustard (*Brassica juncea*) and soil fertility

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ABSTRACT

A field experiment was conducted in two consecutive *rabi* seasons of 2012-13 and 2013-14 at Panwari village, Agra (Uttar Pradesh) to study the effect of rate and source of zinc on productivity, quality and uptake of nutrients in Indian mustard (*Brassica juncea* (L.) Czern and Cosson). The experiment was laid out in randomized block design with two sources (zinc oxide and zinc sulphate) and five levels of zinc (0, 2, 4, 6 and 8 kg Zn/ha) with three replications. The results indicated that significantly taller plants and higher number of sliquae/plant, seed and stover yields were obtained with zinc sulphate as compared to zinc oxide. The plant height, yield attributes, i.e. siliquae/plant, seeds/siliqua and test weight, seed and stover yields of mustard were significantly improved with the increase in the levels of zinc and the highest seed (19.22 q/ha) and stover (55.77 q/ha) yields were recorded with 6 kg Zn/ha. Application of 6 kg Zn/ ha resulted in 22.2% higher seed and 24.7% stover yield than the yield obtained in the control (16.86 q/ha seed and 48.60 q/ha stover). The content and yields of protein and oil remained unaffected by sources of zinc but increased significantly with increasing Zn doses, thus mustard fertilized with 6 kg Zn/ha recorded the highest yield of protein (384.0 kg/ha) and oil (39.3%, 754.7 kg/ha). The maximum value of protein content (21.0%) was recorded with 8 kg Zn/ha. The uptake values of N, P, K and S by mustard seed and straw were not affected with source of zinc but zinc uptake increased significantly with zinc sulphate over zinc oxide. The uptake of nutrients in mustard crop increased significantly up to 6 kg Zn/ha followed by reductions at 8 kg Zn/ha. Nutrient status in post harvest soil was not affected with sources of zinc but improved significantly with Zn levels. The status of available N and Zn improved significantly up to 8 kg/ha, whereas P, K and S contents increase up to 4 kg Zn/ha.

Key words: Indian mustard, Quality, Soil fertility, Sources and levels, Yield, Zinc

Rapeseed-mustard is the third most important oilseed crops after groundnut and soybean in India. The productivity of mustard [*Brassica juncea* (L.) Czernj and Coss] is quite low mainly due to sub-optimal application of fertilizers and cultivation on marginal lands under rainfed conditions. Further, the quality of mustard oil and its cake is an important aspect affected greatly by mineral nutrition. Nutrient management is one of the most important agronomic factors that affects the yield of all the crops. Continuous and imbalanced use of selected fertilizer nutrients have resulted in deterioration of soil health, increasing per unit cost of production and decline in the rate of growth of productivity. The farmers, by and large use mainly nitrogen and phosphorus as plant nutrients in mustard cultivation and as a consequences, deficiencies of Zn and other micronutrients are increasing (Shukla 2011). Zinc is one of the essential plant micronutrient and its importance for crop productivity is similar to that of major nutrients. Zinc has specific and essential physiological functions in plant metabolism. At least four enzymes contain zinc: carbon anhydrase, alcohol dehydrogenase, super oxide dismutase and RNA polymerase, which are involved in photosynthetic CO_2 fixation, anaerobic root respiration, detoxification of super oxide radicals and protection of membrane, lipids and proteins against oxidation. Zinc is important in protein and growth regulators synthesis. Deo and Khandelwal (2009) reported that application of 5 kg Zn/ha significantly increased the seed and stover yield by 14 and 4.9% over control. Zinc deficiency is wide spread throughout the country. Nearly 50% of cultivated soils in India are low in plant available zinc and these soils are under intensive cultivation with no or little application of zinc fertilizers. As low soil Zn status is an important limiting factor responsible for poor yields of the crops, it is imperative to evaluate the response of Zn nutrition on mustard productivity. Zinc deficiency is most commonly corrected by application of zinc sulphate as of its high solubility and low cost. Several zinc products are available in the market but these are beyond the reach of farmers. Since not much work has been done to assess the

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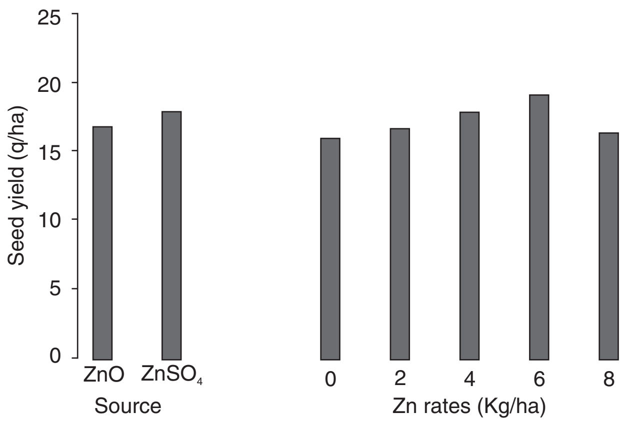

Fig 1 Effect of sources and rates of zinc on seed yield of mustard

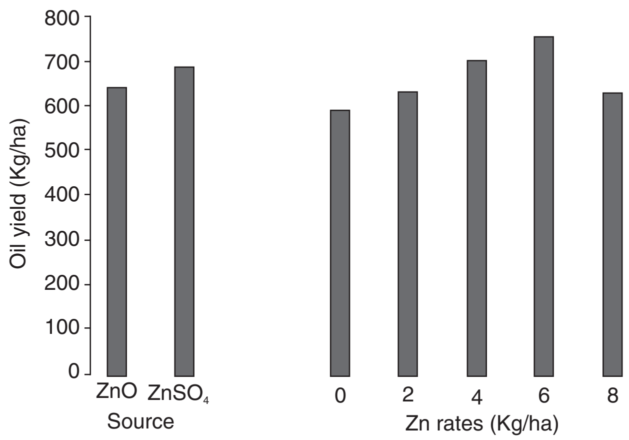

Fig 2 Effect of sources and rates of zinc on oil yield of mustard seed

response of mustard to zinc fertilization irrespective of rate and source of Zn, present study was, therefore, undertaken to study the effect of rate and sources of zinc on yield and quality of Indian mustard.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons of 2012-13 and 2013-14 at farmer's field at Panwari (Agra) which is situated at 27^o 14' N latitude and 77^o 78' longitude at an altitude of 168 m above the mean sea level. The experimental site falls under south-west semi-arid zone and characterized by semi-arid climate with extreme temperature during summer (45 to 48° C) and very low temperature during winter (as low as 2°C). The average rainfall is about 650 mm, most of which is received from June to September. The experimental soil was sandy loam in texture Typic Ustochrept having pH 7.9, organic carbon 3.1 g/kg, available N 152 kg/ha, available P 9.5 kg/ha, available K 106 kg/ha available S 15 kg/ha, and available (DTPA) Zn 0.56 mg/kg. The experiment was laid out in randomized block design with three replications. The treatments consisted of two sources of Zn (zinc oxide and zinc sulphate) five rates of Zn (0, 2, 4, 6 and 8 kg/ha). Mustard (var. Rohini) was sown in third week of October in both the years using 5 kg seed/ha. A basal dose of 100 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Half dose of N and full dose of P and K were applied at the time of sowing of mustard. Remaining N was top dressed after one month of sowing appropriate management practices were adopted to raise the crop. Crop was harvested at maturity. Growth and yield attributes in the crop were recorded at harvest. Seed and stover samples were digested in di-acid mixture of HNO_3: $HClO_4$ (10:4) and sulphur content was determined turbiditimetrically (Chesnin and Yien 1951). Phosphorus, K and Zn in di-acid digest were determined by vanadomolybdate yellow colour method (Jackson 1973),, flame photometer and atomic absorption spectrophotometer, respectively. Nitrogen content was estimated by modified Kjeldahl method and protein content was calculated by multiplying with a factor of 6.25. Oil content in the whole seed of mustard was determined by employing non-destructive method of oil estimation using nuclear magnetic resonance, spectroscope Newport analyzer model MK 111 A. The uptake of nutrients was obtained as product of their concentrations and yield. Post harvest soil samples collected after two years of experiment were air dried, ground to pass through 2 mm sieve and analyzed for organic carbon, available N (Subbiah and Asija 1956), available P (Olsen *et al.* 1954), available K (Hanway and Heidel 1952), available S after extraction with 0.15% $CaCl_2$ solution (Chesnin and Yien 1951), DTPA-Zn (Lindsay and Norvell 1978). The data thus obtained were analyzed statistically using analysis of variance technique for various parameters at 5% level of significance.

RESULTS AND DISCUSSION

Growth and yield

The effect of sources of zinc on plant height and siliqua/plant was significant, but seeds/siliqua and test weight were not affected significantly with sources of zinc. The levels of zinc induced significant increase in plant height and yield attributes, viz. siliquae/plant, seeds/siliqua and test weight of mustard over control (Table 1). Zinc application up to 6 kg/ha recorded significant increase in plant height, siliquae/plant, seeds/siliqua and test height over control. This improvement in growth and yield attributes may be attributed to the fact that Zn plays a key role in plant metabolism, particularly in auxin synthesis which is an essential requirement for plant growth and development. These results are in conformity with the findings of Khan *et al.* (2003) and Singh and Singh (2005) in mustard.

The effect of zinc sources on seed and stover yield of mustard was found to be significant. Zinc sulphate produced higher seed (17.93 q/ha) and stover (50.69 q/ha) yields of mustard compared to zinc oxide (Table 1). This increase in yield may be attributed to higher solubility of zinc sulphate than zinc oxide. With successive increase in Zn levels, seed and stover yield increased significantly up to 6 kg Zn /ha but a further increase in Zn level did not significantly increase the seed and stover yield. The highest seed (17.20 q/ha) and stover (56.77 q/ha) yields were recorded with 6

Table 1 Effect of sources and levels of zinc on growth, yield and quality of mustard (mean of 2 years)

Treatment	Plant height (cm)	Siliquae/ plant	Seeds/ siliqua	Test weight (g)	Yield (q/ha)		Protein in seed (%)	Protein yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
					Seed	Stover				
Sources of zinc										
ZnO	169.0	175.0	14.7	4.8	16.86	48.60	20.0	336.8	38.2	644.0
ZnSO4	171.2	178.2	14.5	4.9	17.93	50.69	20.1	359.9	38.4	688.5
SEm±	0.56	0.61	0.07	0.04	0.18	0.31	0.30	8.17	0.06	10.46
CD (P=0.05)	1.66	1.81	NS	NS	0.53	0.91	NS	NS	NS	31.05
Zinc (kg/ ha)										
0	165.6	169.4	14.4	4.7	15.97	45.52	18.1	288.8	37.1	592.4
2	168.4	174.1	14.6	4.9	16.69	47.57	19.0	317.2	37.9	632.1
4	171.0	178.6	14.7	5.0	17.86	51.24	20.4	364.0	39.2	701.2
6	174.2	181.1	14.9	5.0	19.20	56.77	20.5	384.0	39.3	754.7
8	171.5	179.7	14.6	4.7	16.36	47.14	21.0	343.9	38.4	628.4
SEm±	0.93	1.01	0.12	0.06	0.30	0.51	0.47	12.90	0.11	16.15
CD(P=0.05)	2.75	2.96	0.35	0.17	0.93	1.49	1.37	38.30	0.32	48.68

kg Zn/ ha which registered 20.2 and 24.7 % higher seed and stover yield, respectively over control. This increase in seed and stover yields due to Zn application may be attributed to the fact that Zn is main yield limiting plant nutrient in Zn deficient soils. Applied Zn is reported to enhance the absorption of native as well as added major nutrients and thereby improves overall growth and development of plant and ultimately the seed and stover yield. In addition the beneficial influence of Zn application on the yield of mustard may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of crop (Upadhyay 2012 and Singh *et al.* 2013).

Quality

The oil content in mustard seed was higher with zinc sulphate than that of zinc oxide. However, this effect was non-significant (Table 1). The oil content in seeds increased significantly from 37.1% at control to 39.3% with 6 kg Zn/ ha. Zinc functions in plants largely as a metal activator of enzymes like cysteine di-sulphydrase, di-hydropeptidase, glyceric glycine dipeptidase. Thus, addition of zinc might have activated the enzymes responsible for producing oil and caused higher oil content. Beneficial effect of zinc on oil content was also reported by Khan *et al.* (2003) and Deo and Khandelwal (2009). Significantly higher oil yield (688.5 kg/ha) was recorded with $ZnSO_4$ than ZnO and it was increased to the tune of 6.9 % over ZnO. Amongst the zinc levels, 6 kg Zn/ha recorded maximum and significantly higher oil yield (754.7 kg/ha) of mustard seeds and it was increased to the tune of 162.3 kg/ha over no zinc. Oil yield is a function of oil content and seed yield and both the parameters increased with different levels of zinc, thus resulted in a significant increase in oil yield. Similar findings were reported by Deo and Khandelwal (2009).

The difference in protein content in mustard seed as affected by zinc sources was non-significant. However, a slightly greater amount of protein in mustard seeds was recorded with zinc sulphate (Table 1). Increasing levels of Zn significantly increased the protein content in mustard seed from 18.1 to 21.0 percent with 8 kg Zn/ha. The increase in protein content owing to Zn addition might be attributed to its involvement in the nitrogen metabolism. Upadhyay (2012) reported an increase in protein content with Zn application in mustard seeds. Corresponding application of Zn also increased the protein yield from 288.8 to 394.0 kg/ha. The increases in protein yield were significant up to 6 kg Zn/ha over the control. Since variation in protein content has genetic and biochemical limitation, the protein yield is more influenced by seed yield and thus followed almost trend similar to seed yield. Bhadauria *et al.* (2012) also reported similar results. The sources of zinc had no significant effect on protein production. However the higher values of protein yield were recorded in mustard seed with addition of zinc sulphate over zinc oxide.

Uptake of nutrients

Zinc sulphate as a source of zinc was superior to zinc oxide for utilizing greater amounts of nitrogen by mustard crop. However, the difference between these two sources was statistically non-significant. Nitrogen uptake by mustard seed and stover increased significantly with increasing levels of Zn and the highest N uptake was observed with 6 kg Zn/ha, i.e. 67.2 and 41.6 kg/ha and lowest in the control, i.e. 47.5 and 31.0 kg/ha (Table 2). Thus, the beneficial effect of Zn on photosynthesis and metabolic processes augments the production of photosynthates and their translocation in different plant parts including seed, which ultimately increased the uptake of N in seed and stover. These results are in accordance with the findings of Singh *et al.* (2013). Addition of zinc as zinc sulphate to the soil brought about greater amount of P uptake by mustard crop than that of zinc oxide. This may be attributed to higher production of

Table 2 Effect of sources and levels of zinc on uptake of N, P, K, S (kg/ha) and zinc (g/ha) by mustard crop (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium		Sulphur		Zinc	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Sources of zinc										
ZnO	55.4	34.4	5.9	7.3	9.2	45.0	11.8	7.6	49.2	101.4
$ZnSO_4$	59.2	36.7	6.7	9.0	10.5	47.9	12.7	8.8	56.2	112.1
SEm±	1.52	1.13	0.28	0.57	0.53	0.97	0.34	0.44	1.42	1.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	4.21	3.49
Zinc (kg /ha)										
0	47.5	31.0	5.2	7.1	8.5	40.9	11.0	7.6	40.8	79.6
2	52.2	33.7	6.1	7.8	9.1	44.1	11.6	7.9	47.2	95.2
4	60.1	37.2	6.7	8.9	10.1	48.4	12.8	8.9	55.7	112.1
6	67.2	41.6	8.0	9.9	11.9	54.6	14.6	9.9	65.1	133.3
8	56.7	34.6	5.9	8.6	9.5	44.9	11.8	8.6	55.3	115.9
SEm±	2.40	1.79	0.44	0.89	0.84	1.52	0.52	0.69	2.24	1.86
CD (P=0.05)	7.14	5.32	1.30	2.65	2.49	4.50	1.54	2.07	6.66	5.51

mustard seed and stover due to zinc sulphate application. However, the effect of sources of zinc on P uptake was statistically non–significant. Phosphorus uptake by seed and stover of mustard increased at lower levels of zinc due to increase in yield but at higher level of zinc, it decreased due to reduced P content in seed and stover. This decrease in P uptake with higher dose of zinc might be due to antagonistic effect between P and Zn. Similar results were reported by Jat and Mehra (2007). The uptake of potassium by mustard seed and stover was not affected significantly due to sources of zinc, but higher value of K uptake was recorded with zinc sulphate application. The uptake of K by mustard seed and stover was significantly increased with increasing levels of Zn up to 6 kg Zn/ha. The magnitude of increase in K uptake with 6 kg Zn/ha was 40.0 and 33.5% in seed and stover, respectively over control. The results are in accordance with the findings of Jat and Mehra (2007) and Singh *et al.* (2013). The uptake of sulphur by mustard seed and stover was not affected significantly with the sources of zinc. However, relatively higher uptake value of sulphur was noted with zinc sulphate addition. There was a significant increase in sulphur uptake by mustard seed and stover with the application of Zn up to 6 kg/ha over the control. Thereafter, a reduction in S uptake was noted at higher level of zinc (Singh *et al.* 2013). Zinc sulphate resulted in maximum uptake of Zn in mustard seeds and stover at any level of Zn compared with respective levels of Zn from zinc oxide. This increase may be attributed to increased seed and stover yield of mustard with zinc sulphate. The uptake of Zn by mustard seeds and stover increased significantly with increasing doses of Zn and it was highest with the application of 6 kg Zn/ha. The increase in Zn uptake by seed and stover with 6 kg Zn /ha was 59.5 and 67.4 per cent over the control, respectively.

Table 3 Status of organic carbon and available nutrients in post harvest soil as affected by sources and levels of zinc

Treatment	Org. carbon (g/kg)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Sulphur (kg/ha)	Zinc (kg/ha)
Sources of zinc						
ZnO	3.1	151.4	8.8	108.0	14.1	0.62
$ZnSO_4$	3.3	152.2	8.6	107.6	14.3	0.66
SEm±	0.011	0.84	0.07	0.46	0.08	0.009
CD (P=0.05)	NS	NS	NS	NS	NS	0.026
Zinc (kg/ ha)						
0	3.0	148.0	9.0	104.0	14.2	0.56
2	3.1	150.5	8.9	110.0	14.5	0.60
4	3.2	152.0	8.6	110.0	14.4	0.66
6	3.4	153.0	8.6	107.0	14.2	0.69
8	3.5	155.5	8.4	106.0	13.8	0.72
SEm±	0.017	1.33	0.02	0.64	0.11	0.014
CD (P=0.05)	NS	3.61	0.05	1.74	0.31	0.038

The increase in Zn was in consonance with higher seed and straw yield and increase in Zn content in seeds and stover with increase in Zn levels (Jat and Mehra 2007, Upadhyay 2012).

Soil fertility

The status of organic carbon in post harvest soil was not improved significantly with sources and levels of zinc over control (3.1 g/ kg). The sources of zinc were not effective in enhancing the status of available nitrogen in post harvest soil but levels of zinc enhanced the status of available N in soil and maximum amount was noted with 8 kg Zn/ha. The difference in available N status of the soil due to zinc levels was not significant. The status of available P was not improved significantly with sources of zinc. But P content decreased linearly with every incremental dose of Zn from 2 to 8 kg/ha. The trend was just opposite for DTPA extractable Zn content where the values increased with increasing levels of Zn, though the overall level remained medium. This result implies that phosphorus and zinc content in the soil enjoyed an antagonistic relationship between them. The status of available K and S in post harvest soil was not affected by sources of Zn but higher levels of Zn (6 and 8 kg Zn/ha) tended to decrease the amounts of available S and K in soil over lower levels of Zn (Jat *et al.* 2012).

Conclusion

It is inferred from the present study that soil application of Zn up to a dose of 6 kg/ha is beneficial compared to control for yields of mustard crop. Also an improvement in quality of mustard oil and uptake of nutrients was recorded with zinc application. Therefore, the present study highlights that application of Zn up to a dose 6 kg/ha as zinc sulphate is beneficial for mustard cultivation in alluvial region of western Uttar Pradesh.

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