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Various levels of Sulphur and Zinc fertilization for improving productivity and economics of Mustard (*Brassica juncea* L. Czern)

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Abstract
A study was conducted at Agronomy Research Field, College of Agriculture, Gwalior (M.P.) during *rabi* seasons of 2018-19 and 2019-20. The soil of the experimental field was alluvial and sandy clay loam in texture. Twenty four treatment combinations administered in mustard consisted of 4 sulphur levels (0, 20, 40 & 60 kg ha^{-1}), three Zn levels (0, 2.5 & 5 kg ha^{-1}) and two zinc solubilizing bacteria levels (without zinc solubilizer & with zinc solubilizer) were replicated three times in randomized block design (factorial).Higher value of growth parameters (like; number of leaves plant^{-1}and number of secondary branches plant^{-1}), yield attributes (*viz*.; number of seeds silliquae^{-1}and seed yield plant^{-1}), physiological characteristics (*viz*.; LAI and AGR) as well as computed parameters (*viz*.; seed and stover yield) and net return were recorded significantly under 60 kg ha^{-1} S level, which was statistically at par with 40 kg ha^{-1} S level; while lower value was noted under 0 kg ha^{-1} S level. Maximum value of various parameters were recorded under 5 kg ha^{-1} Zn level, which was statistically at par with 2.5 kg ha^{-1} Zn level; while significantly minimum value was noted under 0 kg ha^{-1} Zn level. Significantly superior value of different attributes was noted with zinc solubilizer; while minimum value was recorded without zinc solubilizer. In case of net return; significantly higher net return was noted under 40 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51674 ha^{-1}), which was statistically at par with 60 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51654 ha^{-1}); while lower value was recorded under 0 kg ha^{-1} S level + 0 kg ha^{-1} Zn level (Rs.38968 ha^{-1}).

Keywords: Mustard, net return, physiological characteristics, yield attributes

Introduction

Rapeseed and mustard is the most common cropping system in mustard growing belt of Rajasthan and Madhya Pradesh, rapeseed-mustard crops in India comprise traditionally grown indigenous species namely Toria (*Brassica rapa* L. var. Toria), Brown sarson (*Brassica rapa* L. var. brown sarson), Yellow sarson (*Brassica rapa* L. var. yellow sarson), Indian mustard (*Brassica juncea*), Black mustard (*Brassica nigra*) and Taramira (*Erucasativa* L. Vesicaria). The requirement of vegetable oil and fat will be the much higher in coming years in view of ever increasing population. Among the oilseed crop rapeseed mustard occupy rank next to soybean in acreage and production. Indian mustard (*Brassica juncea* L. Czern) is the most important *rabi* oilseed crops in India.

Identification of critical input to enhance the mustard production is need of hour. Apart from Improved varieties and judicious irrigation; use of balanced fertilizer is critical for realizing higher yield. Indian soil are becoming deficient in N, P, K along with S, Zn and B due to Intensive cultivation and use of high analysis fertilizers (Srivastava *et al*., 2006) [10]. In recent past, sulphur has emerged as a vital nutrient for increasing the productivity and quality of all the crops; especially oilseeds and pulses. Sulphur influences yield and quality of the produce as it involved in the synthesis of essential amino acids like methionine, cysteine and cysteine, and oils in oilseeds, being vital component of co-enzyme involved in oils synthesis in oilseeds. Recently, more than 50% of Indian soils have been reported to be deficient in sulphur. Deficiency of micronutrients in soils is another constraint, which is limiting the productivity of crops. Zinc deficiency appears to be most wide spread due to intensive agriculture, use of high analysis fertilizers and limited or no use of zinc fertilizers by farmers. Tandon (2010) [12] 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%. Highest Zn deficiency in alluvial soils may be attributed to very low organic carbon, very high sand content, large number of ravines and top soil losses through run-off (Yadav and Meena, 2009) [16]. Beside inorganic fertilizers sources of nutrients, bio-fertilizers such as rhizobium, azotobacter, azospirillum, PSB, AM etc. are being used to meet partially the nutrient requirement of crops. In this series of bio-fertilizers zinc solubilizer, a bio-fertilizer has been developed to improve the availability of native zinc in the soil. Zinc solubilizer is a new entry in the group of bio-fertilizers and no-work has been carried on its efficiency to substitute zinc requirement of crops under field conditions. Zinc has been reported to interact with other plant nutrient. Under Zn and S; synergistic, antagonistic and no interaction have been reported and the relationship between S and Zn is not clear-cut (Takkar and Colin, 1989) [11]. S and Zn interaction can be positive or absent depending on the degree of their deficiency and crop requirement.

Materials and Methods

To carry out the investigation during *rabi* seasons of 2018-19 and 2019-20 at Agronomy Research Field, College of Agriculture, Gwalior (M.P.). The area was uniform topography. The experimental field was gentle slope provides free drainage of excessive water, which is an essential condition for mustard crop growing. Gwalior is situated at 26°13' N latitude and 76°14' E longitudes at an altitude of 212 meters above the mean sea level and enjoying the sub-tropical and semi-arid climate with extreme hot about 46 °C in summer and minimum temperature below 1 °C in the winter season. The annual rainfall ranges between 700 to 800 mm, most of which is received from end of June to end of September. Drought is a common feature due to the scanty and uneven distribution of rainfall. The soil of the experimental field was alluvial and sandy clay loam in texture.

Twenty four treatment combinations administered in mustard consisted of 4 sulphur levels (0, 20, 40 & 60 kg ha^{-1}), three Zn levels (0, 2.5 & 5 kg ha^{-1}) and two zinc solubilizing bacteria levels (without zinc solubilizer & with zinc solubilizer) were replicated three times in randomized block design (factorial). The 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per hectare were optimum dose (100%) for NPK. Half dose of the N in the form of urea was applied as basal and remaining quantity of nitrogen was top dressed after first irrigation. The Complete Dose of P and K were applied by DAP and muriate of potash at the time of sowing. Mustard variety 'Rohini' was sown at row spacing of 30 cm with seed rate of 5 kg ha^{-1}. All recommended practices were followed during crop growing season. All parameters were statistically analyzed by null method as described by Fisher (1958) [1] and Panse and Sukhatme (1978) [17].

Results and Discussion

The results have revealed several points of interest are discussed in this chapter. During the course of discussion an effort has been made to establish relationship between various treatments and yield of the crop. All findings of research have been described as per pooled data.

The various treatments significantly affected the growth parameters like; number of secondary branches plant^{-1} and number of leaves plant^{-1}at all stages of crop growth except their interactions (Table 1). Significantly maximum value of growth parameters was recorded under 60 kg/ha S level, which was statistically at par with 40 kg/ha S level; while minimum value was observed under 0 kg/ha S level at all growth stages. Higher value of growth parameters was registered significantly under 5 kg/ha Zn level, which was statistically at par with 2.5 kg/ha Zn level; while lower value was recorded under 0 kg/ha Zn level at all growth stages. Superior value of growth parameters was noted with zinc solubilizer; while significantly minimum value was recorded without zinc solubilizer at all growth stages. The increase in growth attributes might be due to adequate availability of sulphur and zinc attributed to better nutritional environment for plant growth at active vegetative stages as a result of enhancement in cell multiplications, cell elongation and cell expression in the plant body. The results of present investigation are also in agreement with the findings of Singh *et al*. (2016) [8], Sahu *et al*. (2018) [5] and Verma *et al*. (2020) [15].

The yield attributes *viz*.; number of seeds silliquae^{-1}and seed yield plant^{-1}were significantly affected by different treatments except their interactions (Table 1). Higher number of yield attributeswas recorded significantly under 60 kg ha^{-1} S level (13.14and 12.83 g; respectively), which was statistically at par with 40 kg ha^{-1} S level (12.99 and 12.33 g; respectively); while lower value was noted under 0 kg ha^{-1} S level (11.19 and 7.80 g; respectively). Significantly maximum number of yield attributes was registered under 5 kg ha^{-1} Zn level (12.95and12.28 g; respectively), which was statistically at par with 2.5 kg ha^{-1} Zn level (12.83and11.92 g; respectively); while minimum value was recorded under 0 kg ha^{-1} Zn level (11.73and9.11 g; respectively).Superior value of yield attributes was observed with zinc solubilizer (12.80and11.93 g; respectively); while significantly minimum value was recorded without zinc solubilizer (12.21and10.28 g; respectively). The probable reason may be that adequate supply of all the nutrients (sulphur and zinc) which resulted in greater accumulation of carbohydrates, amino acids and their translocation to the productive organs, which, in-turn improved in all the growth and yield attributing characters have also been reported by Singh *et al*. (2016) [8], Singh and Pandey (2017) [7], Singh *et al*. (2017) [6], Nath *et al*. (2018) [18], Meena *et al*. (2018) [2] and Rana *et al*. (2018) [4].

The physiological parameters *viz*.; LAI and AGR were significantly influenced various treatments at all stages/intervals of crop growth except their interactions (Table 1). Significantly higher value of physiological parameters were recorded under 60 kg ha^{-1} S level, which was statistically at par with 40 kg ha^{-1} S level; while lower value was noted under 0 kg ha^{-1} S level. Maximum value of physiological parameters were recorded under 5 kg ha^{-1} Zn level, which was statistically at par with 2.5 kg ha^{-1} Zn level; while significantly minimum value was observed under 0 kg ha^{-1} Zn level. Superior value of physiological parameters was noted significantly with zinc solubilizer; while minimum value was recorded without zinc solubilizer. 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 Sipai *et al*. (2016) [9] and Rana *et al*. (2018) [4].

The computed parameters *viz*.; seed yield and stover yield were significantly influenced various treatments and S x Z & Z x I interactions except other interactions (Table 1, 2 & 3). Significantly higher value of computed parameters were registered under 60 kg ha^{-1} S level (1755 kg ha^{-1}and 3979 kg ha^{-1}; respectively), which was statistically at par with 40 kg ha^{-1} S level (1734 kg ha^{-1}and 3957 kg ha^{-1}; respectively); while lower value was recorded under 0 kg ha^{-1} S level (1478 kg ha^{-1}and 3632 kg ha^{-1}; respectively). Maximum value of computed parameters were recorded under 5 kg ha^{-1} Zn level (1750 kg ha^{-1} and3938 kg ha^{-1}; respectively),which was statistically at par with 2.5 kg ha^{-1} Zn level (1710 kg ha^{-1} and 3927 kg ha^{-1}; respectively); while significantly minimum value was noted under 0 kg ha^{-1} Zn level (1541 kg ha^{-1} and 3742 kg ha^{-1}; respectively).Significantly superior value of seed yield and biological yield were noted with zinc solubilizer (1696 kg ha^{-1} and 3918 kg ha^{-1}; respectively); while minimum value was recorded without zinc solubilizer (1638 kg ha^{-1} and 3820 kg ha^{-1}; respectively).Higher value of seed yield was registered under 60 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (1856 kg ha^{-1}),which was statistically at par with 40 kg ha^{-1} S level + 2.5 kg ha^{-1} Zn level (1837 kg ha^{-1}); while significantly lower value was recorded under 0 kg ha^{-1} S level + 0 kg ha^{-1} Zn level (1440 kg ha^{-1}).Significantly maximum seed yield was noted under 5 kg ha^{-1} Zn level + with zinc solubilizer (1758 kg ha^{-1}),which was statistically at par with 5 kg ha^{-1} Zn level + without zinc solubilizer (1742 kg ha^{-1}); while minimum value was recorded under 0 kg ha^{-1} Zn level + without zinc solubilizer (1481 kg 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 investigation are supported by Singh and Pandey (2017) [7], Nath *et al*. (2018) [18] and Verma and Dawson (2018) [14].

The net return was significantly influenced by various treatments as well as interactions except S x I and S x Zn x I interactions (Table 1, 2 & 3). Significantly higher value of net return was recorded under 60 kg ha^{-1} S level (Rs.48102 ha^{-1}), which was statistically at par with 40 kg ha^{-1} S level (Rs.48008 ha^{-1}); while lower value was registered under 0 kg ha^{-1} S level (Rs.39759 ha^{-1}). Maximum value of net returnwas noted under 5 kg ha^{-1} Zn level (Rs.48678 ha^{-1}), which was statistically at par with 2.5 kg ha^{-1} Zn level (Rs.47382 ha^{-1}); while significantly minimum value was recorded under 0 kg ha^{-1} Zn level (Rs.41459 ha^{-1}). Superior value of net return was recorded significantly with zinc solubilizer (Rs.46583 ha^{-1}); while minimum value was registered without zinc solubilizer (Rs. 45096 ha^{-1}).

Significantly higher value of net return was recorded under 40 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51674 ha^{-1}),which was statistically at par with 60 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51654 ha^{-1}); while lower value was recorded under 0 kg ha^{-1} S level + 0 kg ha^{-1}Zn level (Rs.38968 ha^{-1}). Maximum value of net return was registered under 5 kg ha^{-1} Zn level + without zinc solubilizer (Rs.48765 ha^{-1}), which was statistically at par with 5 kg ha^{-1} Zn level + with zinc solubilizer (Rs.48590 ha^{-1}); while minimum value was recorded under 0 kg ha^{-1} Zn level + without zinc solubilizer (Rs.39484 ha^{-1}). These results are in tune with the findings of Singh and Pandey (2017) [7], Sahu *et al*. (2018) [5] and Upadhyay *et al*. (2018a) [13].

Table 1: Effect of sulphur and zinc fertilization on growth& physiological parameters, yield attributes, computed parameters and economics of mustard (Pooled)

Treatment	No. of leaves plant^{-1}	No. of secondary branches plant^{-1}	No. of seeds Silliquae^{-1}	Seed yield plant^{-1} (g)	LAI at 90 DAS	AGR at 60 DAS	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Net Return (Rs. ha^{-1})
Sulphur Level (S)									
0 kg ha^{-1}	56.71	9.53	11.19	7.80	4.81	0.292	1478	3632	39759
20 kg ha^{-1}	64.30	10.81	12.68	11.44	7.05	0.331	1702	3906	47490
40 kg ha^{-1}	65.72	11.05	12.99	12.33	7.59	0.339	1734	3957	48008
60 kg ha^{-1}	66.69	11.21	13.14	12.83	7.90	0.343	1755	3979	48102
S.E(m)±	0.81	0.13	0.15	0.41	0.25	0.007	11	46	438
CD at 5%	2.29	0.37	0.42	1.15	0.71	0.020	30	140	1238
Zinc Level (Z)									
0 kg ha^{-1}	59.62	10.02	11.73	9.11	5.61	0.307	1541	3742	41459
2.5 kg ha^{-1}	64.95	10.92	12.83	11.92	7.34	0.334	1710	3927	47382
5 kg ha^{-1}	65.49	11.01	12.95	12.28	7.56	0.337	1750	3938	48678
S.E(m)±	0.70	0.11	0.13	0.35	0.22	0.006	9	40	379
CD at 5%	1.98	0.32	0.36	0.99	0.61	0.017	26	112	1072
Zinc Solubilizing Bacteria (I)									
Without Zinc Solubilizer	61.83	10.40	12.21	10.28	6.33	0.318	1638	3820	45096
With Zinc Solubilizer	64.87	10.91	12.80	11.93	7.35	0.334	1696	3918	46583
S.E(m)±	0.57	0.09	0.11	0.29	0.18	0.005	7	32	309
CD at 5%	1.62	0.26	0.30	0.81	0.50	0.014	21	92	875
Interaction									
S x Z	NS	NS	NS	NS	NS	NS	S	NS	S
S x I	NS	NS	NS	NS	NS	NS	NS	NS	NS
Z x I	NS	NS	NS	NS	NS	NS	S	NS	S
S x Z x I	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Interaction effect of sulphur and zinc fertilization on computed parameters and economics of mustard (Pooled)

Treatment	Seed yield (kg ha^{-1})				Net Return (Rs. ha^{-1})			
S/Z	0 kg ha^{-1}	20 kg ha^{-1}	40 kg ha^{-1}	60 kg ha^{-1}	0 kg ha^{-1}	20 kg ha^{-1}	40 kg ha^{-1}	60 kg ha^{-1}
0 kg ha^{-1}	1440	1547	1579	1599	38968	41944	42449	42476
2.5 kg ha^{-1}	1489	1754	1785	1811	40026	49425	49901	50177
5 kg ha^{-1}	1503	1804	1837	1856	40283	51100	51674	51654
S.E(m)±	18				758			
CD at 5%	52				2144			

Table 3: Interaction effect of zinc and zinc solubilizing bacteria fertilization on computed parameters and economics of mustard (Pooled)

Treatment	Seed yield (kg ha^{-1})			Net Return (Rs. ha^{-1})		
Z/I	0 kg ha^{-1}	2.5 kg ha^{-1}	5 kg ha^{-1}	0 kg ha^{-1}	2.5 kg ha^{-1}	5 kg ha^{-1}
Without Zinc Solubilizer	1481	1691	1742	39484	47040	48765
With Zinc Solubilizer	1601	1728	1758	43435	47725	48590
S.E(m)±	13			536		
CD at 5%	37			1516		

Conclusions

Higher value of growth parameters, yield attributes, physiological characteristics as well as computed parameters and net return were recorded significantly under 60 kg ha^{-1} S level, which was statistically at par with 40 kg ha^{-1} S level; while lower value was noted under 0 kg ha^{-1} S level.

Maximum value of growth parameters, yield attributes, physiological characteristics as well as computed parameters, net return were recorded under 5 kg ha^{-1} Zn level, which was statistically at par with 2.5 kg ha^{-1} Zn level; while significantly minimum value was noted under 0 kg ha^{-1} Zn level.

Significantly superior value of growth parameters, yield attributes, physiological characteristics as well as computed parameters and net return were noted with zinc solubilizer; while minimum value was recorded without zinc solubilizer.

In case of interaction (S x Zn); significantly higher value of net return was recorded under 40 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51674 ha^{-1}), which was statistically at par with 60 kg ha^{-1} S level + 5 kg ha^{-1} Zn level (Rs.51654 ha^{-1}); while lower value was recorded under 0 kg ha^{-1} S level + 0 kg ha^{-1} Zn level (Rs.38968 ha^{-1}).

In case of other interaction (Zn x Zinc solubilizing bacteria); maximum value of net return was registered under 5 kg ha^{-1} Zn level + without zinc solubilizer (Rs.48765 ha^{-1}), which was statistically at par with 5 kg ha^{-1} Zn level + with zinc solubilizer (Rs.48590 ha^{-1}); while minimum value was recorded under 0 kg ha^{-1} Zn level + without zinc solubilizer (Rs.39484 ha^{-1}).

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Conflict of interest: None

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