RESEARCH ARTICLE

INFLUENCE OF SULPHUR AND ZINC ON GROWTH, YIELD, QUALITY AND ECONOMICS OF INDIAN MUSTARD (*BRASSICA JUNCEA*) UNDER RAINFED CONDITIONS

Pradeep Kumar Rana, Pawan Sirotia, U.S. Mishra, Baijnath Yadav* and Abhilesh Pratap Singh

Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna- 485 780 (M.P.)

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Abstract: A field experiment was conducted during the winter seasons of 2013-14 and 2014-15 in Chitrakoot – Satna, Madhya Pradesh, India, to study the effects of 5 sulphur levels (0, 15,30,45 and 60 kg S ha^{-1}) and 4 zinc levels (0, 2.5, 5.0 and 7.5 kg Zn ha^{-1}) on rainfed Indian mustard (cv. Pusa Tarak). Progressive increase in P and Zn levels increased the yield attributes and seed yield, but the increase in seed yield was significant only up to 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1}. Seed yield increased significantly up to 45 kg S ha^{-1} and 5.0 kg Zn ha^{-1} application. Significantly higher seed yield (1685.2 kg ha^{-1}) was recorded with 45 kg S x 7.5 kg Zn ha^{-1} followed by 60 kg S x 7.5 kg Zn, 30 kg S x 5.0 kg Zn and 45 kg S x 5.0 kg Zn^1 and these treatments combination were comparable from each other. Oil and protein content also increased up to 30 kg S and 5 kg Zn ha^{-1}.

Keywords: Mustard, Quality, Seed yield, Sulphur, Zinc

INTRODUCTION

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). It is predominantly cultivated in Rajasthan, U.P., Haryana, Madhya Pradesh, and Gujarat as rabi crops. It is also grown under some non - traditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. The crop can be raised well under both irrigated and rainfed conditions. Introduction of high yielding cultivars, increased cropping intensity, application of sulphur and zinc free fertilizers and limited addition of organic manures have caused sulphur and zinc deficiency in most of soils. Judicious uses of fertilizer have played a vital role in increasing the production of oilseed crops. Oilseed crops particularly belonging to "Cruciferae" have relatively higher S requirement owing to their high content of sulphur containing amino acids and essential oil (Aulakh *et al.* 1980). Zinc application also influenced the oil content in oilseed crop (Muralidharudue and Singh, 1990). The deficiency of S and Zn is increasing due to continuous use of NPK fertilizers and increased cropping intensity with HYV, and is more conspicuous in light textured soils low in organic matter content. The wide-spread deficiency of S and Zn and response of crops to their application are reported from several parts of country. Keeping above facts in view, the present study was undertaken to evaluate the effect of sulphur and zinc on growth, yield and quality of mustard in rainfed conditions.

MATERIALS AND METHODS

A field experiment was conducted at Rajaula Research Farm, Faculty of Agricultural Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot – Satna, Madhya Pradesh (25° 10' N and 80° 52' E) during the *Rabi* seasons of 2013-14 and 2014-15. The experimental soil was sandy loam in texture and having pH 7.8, organic carbon content 0.37%, and available N, P & K was 213.2, 14.56 & 219.5 kg ha^{-1} respectively. The available S and Zn was 12.83 and 0.53 mg kg^{-1}. Total twenty treatment (5 levels of sulphur i.e. 0, 15, 30, 45 and 60 kg ha^{-1} and 4 levels of zinc i.e. 0, 2.5, 5.0 and 7.5 kg ha^{-1}) were laid out in randomized block design with three replications. Sulphur and zinc 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 was also applied through urea, DAP and muriate of potash at the time of sowing. Mustard variety Pusa Tarak was sown in rows at 30 cm apart using 5 kg seed ha^{-1} on second fortnight of October and all other cultivation practices were adopted as per recommendations. Five random plants were sampled from each plot at maturity for growth and yield attributes characters and seed yield and harvest index were calculated on the basis of seed and stover yield under net plot area. Under economics, net returns and B: C ratio was calculated on the basis of prevailing market price of the inputs and produce. Oil content in seed was determined by Soxhlit's oil extraction method and protein content was observed by multiplying factor in total N content in seed (A.O.A.C., 1984). The entire data was analysed statistically by using ANOVA.

*Corresponding Author

RESULTS AND DISCUSSION

Effect of sulphur

Growth and yield attributes characters:

The application of different levels of sulphur and zinc with recommended dose of NPK, increased almost all growth and yield attributing characters significantly, however, the trend of increase was towards positive direction. the increasing level of sulphur up to 60 kg ha^{-1} increase the plant height and number of branches $plant^{-1}$ significantly at harvest stage. A maximum value was observed with 60 kg S ha^{-1} which was significantly higher to control and 15 kg and statistically at par with 30 and 45 kg S ha^{-1}. Application of 60 kg S ha^{-1} showed the best results in different yield attributes component but the effect of 30 and 45 kg S ha^{-1} was found at par with number of siliquae $plant^{-1}$ and test weight On the other side, number of seeds $siliquae^{-1}$, biomass $plant^{-1}$ were maximum under 60 kg S ha^{-1} which was significantly higher over control, 15 and 30 kg S ha^{-1} but at par with 45 kg S ha^{-1}. The probable reason may be that adequate supply of all the nutrients, particularly sulphur 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 (Singh and Meena, 2004).

Seed and stover yield

Application of sulphur significantly increased the seed and stover yield with S dose up to 30 kg ha^{-1}. Application of 30 kg S ha^{-1} significantly increased the seed yield by 53.4 and 28% on pooled basis over control and 15 kg S ha^{-1}, respectively. Maximum yield (1519.0 kg ha^{-1}) was observed with the application of 45 kg S ha^{-1} which was significantly higher to control and 15 kg S ha^{-1} but statistically at par with 30 and 60 kg S ha^{-1} treatments. This might be due to more accumulation of amino acids and amide substances and their translocation to reproductive organs which influenced growth and yield due to application of sulphur (Dongarkar *et al*., 2005). Similar results were also reported by Jat and Mehra (2007).

Quality parameters

It is clear from table-3 that the increasing levels of sulphur up to 60 kg ha^{-1} increased the oil and protein content but show significant difference only up to 30 kg ha^{-1} thereafter difference was non-significant. Maximum oil content (39.97%) was recorded with 60 kg S ha^{-1} which was significantly higher to control and 15 kg S ha^{-1} but was statistically at par with 30 and 45 kg S ha^{-1} treatments. The increase in oil content on addition of sulphur might be associated with increase in acetyl-CoA carbohydrate activity through the enhancement of acetyle CoA concentration (Ahmad *et al.* 2000). Maximum protein content (21.03%) was recorded with 60 kg S ha^{-1} which was acids and S containing amino acids, such as cystine, cysteine and methionine significantly higher to control and 15 kg S ha^{-1} but was statistically at par with 30 and 45 kg S ha^{-1} because S is required for the synthesis of fatty which are essential components of protein (Havlin *et al.* 1999). Maximum oil yield (607.6 kg ha^{-1}) and protein yield (318.33 kg ha^{-1}) was recorded with 45 kg S ha^{-1} which was significantly higher to control and 15 kg S ha^{-1} but was statistically at par with 30 and 60 kg S ha^{-1} treatments.

Effect of Zinc

Growth and yield attributes characters:

Application of zinc recorded significantly higher taller plant and higher number of branches as compared to control. Maximum height and number of branches noted with 7.5 kg Zn ha^{-1} treatment but was statistically at par with 5.0 kg Zn ha^{-1}. The yield attributes viz. number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, and 1000 seed weight increased due to increasing levels of zinc. Maximum values were observed with 7.5 kg Zn ha^{-1} but closely followed by 5.0 kg Zn ha^{-1} levels which were significantly higher to control and 2.5 kg Zn ha^{-1} and both were comparable with each other. The findings confirm the results of Yadav *et al.* (2007) and Zizala *et al.* (2008).

Seed and Stover yield

Seed and stover yield of mustard increased significantly with increasing levels of Zn up to 5.0 kg Zn ha^{-1}. The maximum seed yield recorded with 5.0 kg Zn ha^{-1} application was at par with 7.5 kg Zn ha^{-1}. The application of 5.0 kg Zn ha^{-1} increased the seed yield by 23.8 and 12.7% and stover yield by 15.3 and 8.2% over control and 2.5 kg Zn ha^{-1}, respectively. Application of 2.5 kg Zn ha^{-1} increased the seed yield by 9.9% over control. 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 Meena *et al.* (2006) and Deo and Khandelwal (2009).

Quality parameters

Maximum oil content (40.22%) and oil yield (577.6 kg ha^{-1}) was noted with 7.5 kg Zn ha^{-1} which was significantly higher over control and 2.5 kg Zn ha^{-1} but was at par with 5.0 kg Zn ha^{-1} treatment. It is revealed from result that application of 5.0 kg Zn ha^{-1} produced 3.35 and 0.89% higher oil content over to control and 2.5 kg Zn ha^{-1} treatments. Increase in oil content in mustard seed with Zn application might be due to activation of NADPH dependent dehydrogenase involved in fat synthesis by Zn (Pable *et al.*, 2010). Highest protein content (20.88%) and protein yield (299.70 kg ha^{-1}) was noted with 5.0 kg Zn ha^{-1} which was significantly higher over control and 2.5 kg Zn ha^{-1} but was at par with 7.5 kg Zn ha^{-1} treatment. The increased protein content in mustard seed with Zn application might be due to the application of Zn increased Nmetabolism, which enhanced accumulation of amino acids and increased the rate of protein synthesis and consequently, protein content in grain. Zn application in soil enhanced the Zn concentration in the plant which is associated with RNA and ribosome induction the result of which accelerates protein synthesis (Sonune *et al*. 2001).

Interaction effect of sulphur and zinc on seed yield

The interaction effect of sulphur and zinc on seed yield was found to be significant (Table-2). Significantly highest seed yield (1685.2 kg ha^{-1}) was recorded with 45 kg S x 7.5 kg Zn ha^{-1} followed by 60 kg S x 7.5 kg Zn, 30 kg S x 5.0 kg Zn and 45 kg S x 5.0 kg Zn^{1} and these treatments combination were comparable from each other. Whereas minimum seed yield (725.5 kg ha^{-1}) was noted with control of both treatments which inferior in all the treatment combinations. The findings of present investigation are supported by Jat and Mehra (2007).

Table 1. Effect of different levels of sulphur and zinc on growth, yield attributes and yield parameters of mustard

Treatment	Plant height (cm)	Number of branches	Bio mass (g $plant^{-1}$)	Number of siliquae $plant^{-1}$	Number of seeds $siliqua^{-1}$	Test weight (g)	Seed yield (kg ha^{-1})	Harvest index (%)
Sulphur levels (S)								
S_0 : Control	163.0	15.57	27.72	211.8	11.07	3.21	958.5	26.11
S_1 : 15 kg S ha^{-1}	178.7	17.50	32.92	237.8	11.66	3.38	1148.8	27.87
S_2 : 30 kg S ha^{-1}	189.4	18.83	40.23	285.4	12.11	3.59	1469.9	29.62
S_3 : 45 kg S ha^{-1}	192.1	18.98	42.24	289.8	12.28	3.63	1519.0	29.41
S_4 : 60 kg S ha^{-1}	192.5	19.14	42.55	287.9	12.50	3.65	1507.6	29.10
S.E m.±	**1.9**	**0.20**	**0.44**	**4.0**	**0.09**	**0.03**	**19.0**	**0.21**
C.D. (5%)	**5.4**	**0.56**	**1.27**	**11.6**	**0.26**	**0.08**	**54.3**	**0.61**
Zinc levels (Zn)								
Zn_0 : Control	165.2	15.89	32.71	204.9	10.99	3.20	1155.7	27.60
Zn_1 : 2.5 kg Zn ha^{-1}	181.4	17.81	35.99	267.4	11.52	3.44	1269.9	28.27
Zn_2 : 5.0 kg Zn ha^{-1}	190.9	19.05	39.74	288.2	12.52	3.65	1430.9	29.13
Zn_3 : 7.5 kg Zn ha^{-1}	195.1	19.27	40.10	289.6	12.74	3.68	1426.6	28.70
S.E m.±	**1.7**	**0.18**	**0.40**	**3.6**	**0.08**	**0.02**	**17.0**	**0.19**
C.D. (5%)	**4.9**	**0.50**	**1.14**	**10.4**	**0.23**	**0.07**	**48.6**	**0.54**

Table 2. Interaction effect of sulphur and zinc on seed yield (kg ha^{-1}) of mustard (pooled data of two years)

Zn levels (kg ha^{-1})	Sulphur levels (kg ha^{-1})					
	Control	15 kg	30 kg	45 kg	60 kg	Zn-Mean
Control	752.5	1059.3	1250.0	1334.0	1382.7	**1155.7**
2.5 kg	856.2	1209.9	1434.6	1448.2	1400.6	**1269.9**
5.0 kg	1197.5	1144.5	1635.8	1608.7	1567.9	**1430.9**
7.5 kg	1027.8	1181.5	1559.3	1685.2	1679.0	**1426.6**
S-Mean	**958.5**	**1148.8**	**1469.9**	**1519.0**	**1507.6**	
SEm (±)	**37.9**					
CD (P=0.05)	**108.6**					

Table 3. Effect of different levels of sulphur and zinc on quality and economics parameters of mustard

Treatment	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
Sulphur levels (S)						
S_0 : Control	36.50	350.8	19.51	188.4	25126	2.46
S_1 : 15 kg S ha^{-1}	38.33	441.1	20.10	231.1	32785	2.86
S_2 : 30 kg S ha^{-1}	39.61	584.3	20.81	306.4	46011	3.56
S_3 : 45 kg S ha^{-1}	39.85	607.6	20.92	318.3	**47844**	**3.60**
S_4 : 60 kg S ha^{-1}	39.97	604.2	21.03	317.3	47055	3.51
S.E m.±	**0.21**	**7.9**	**0.11**	**4.21**	-	-
C.D. (5%)	**0.61**	**22.6**	**0.32**	**12.06**	-	-
Zinc levels (Zn)						
Zn_0 : Control	36.46	421.9	19.83	230.7	33474	2.94
Zn_1 : 2.5 kg Zn ha^{-1}	38.92	498.6	20.37	260.3	36905	2.97
Zn_2 : 5.0 kg Zn ha^{-1}	39.81	572.3	20.88	299.7	**42308**	**3.10**
Zn_3 : 7.5 kg Zn ha^{-1}	40.22	577.6	20.82	298.6	40793	2.89
S.E m.±	**0.19**	**7.0**	**0.10**	**3.8**	**-**	**-**
C.D. (5%)	**0.55**	**20.2**	**0.28**	**10.8**	**-**	**-**

Economics:

The results (Table-3) revealed the maximum net return was found under 45 kg S ha^{-1} followed by 60 kg S ha^{-1} whereas, maximum B:C ratio (3.60) was obtained under 45 kg S ha^{-1} closely followed by 30 kg S ha^{-1} treatment with 3.56 B: C ratio. This may be because of the difference in yield between 30 and 45 kg S ha^{-1} was at par and cost of cultivation was lesser with 30 kg S ha^{-1}. Under different levels of zinc, maximum net return and B:C ratio obtained under 5.0 kg Zn ha^{-1} followed by 7.5 and 2.5 kg Zn ha^{-1}. This may be because of the difference in yield between 7.5 and 5.0 kg Zn ha^{-1} was at par and cost of cultivation was lesser with 5.0 kg Zn ha^{-1}. Similar findings were also reported by Kumar and Trivedi (2012).

CONCLUSION

With a view to draw definite conclusion from the results of present investigation, the seed yield, monetary returns and B:C ratio have been the major considerations. On the basis of the experimental findings, it is concluded that the application of 30 kg S ha^{-1} and 5.0 kg Zn ha^{-1} can be benifical for rainfed mustard in chitrakoot region of Satna district of Madhya Pradesh.

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