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Effect of Sulphure Levels on Mustard Crops

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A B S T R A C T

Mustard is second most important edible oilseed crop after groundnut, accounts nearly 30% of the total oilseeds produced in India. India is one of the largest rapeseed-mustard growing countries in the world, occupying the first rank in area and second in production next to China. Total area under rapeseed and mustard in India is 5.92 million hectares with a production of 6.78 million tonnes and productivity of 1145 kg ha^{-1}.

Keywords

Growth parameters, Yield and Yield attributes, Quality parameter and Nutrients uptake

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Introduction

Sulphur is the fourth major plant nutrient after nitrogen, phosphorus and potassium for Indian agriculture. It is essential for synthesis of amino acids, proteins, oils, and a component of vitamin A and activates enzyme system in plant. Three amino acids viz. methionine (21% S), cysteine (26% S) and cystine (27%S) contain S which are the building blocks of proteins about 90% of sulphur is present in these amino acids. Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in oilseeds. Adequate sulphur is therefore very much crucial for oilseed crops.

The literature on sulphure levels on mustard crop has been well documented. In this article effort has been made to review the literature available on Effect of sulphur levels on mustard crops. The effect of sulphur levels on growth character, yield attributes, yield, nutrients uptake, quality characters and economics were presented here.

Growth parameters

Kumar and Yadav (2007) reported that the plant height increased significantly with each increment in the dose of sulphur up to 15 kg S ha-1. However, the differences in plant height due to further increase in the dose of S were not significant. Application of 30 and 45 kg S ha-1 significantly increased the value of leaf area index. An increase in the level of S significantly improved the dry matter accumulation.

Makeen *et al.,* (2008) reported that the impact of different levels of sulphur on the dry weight of mustard resulted in increase in dry weight with the most favorable response was 60 kg S ha^{-1}. These results are in concurrence with that of (Aulkh *et al.,* 1977).

The higher number of leaves at 90 DAS was obtained form 60 kg S ha^{-1} and lowest from the control. Number of leaves increased gradually during the different stages of growth 60 kg S ha^{-1} resulted in best response on leaves after 90 DAS. The number of leaves increased to 104; similarly mustard attained maximum height at 90 DAS.

Khatkar *et al.,* (2009) reported that highest plant height and maximum plant dry weight were recorded with higher doses of S fertilization. Kapur *et al.,* (2010) reported that plant height of mustard was recorded significantly higher with application of 60 kg S ha^{-1} but it was at par with 45 kg S ha^{-1} and 30 kg S ha^{-1} levels.

Jat *et al.,* (2012) reported that application of 20 kg S ha-1 significantly increased in plant height over control at all the stages of growth except at 30 days after sowing but the highest plant height was observed at 60 kg S ha^{-1}. The results are in agreement with those of Buganova *et al.,* (1975).

Pachauri *et al.,* (2012) reported that various levels of sulphur significantly influenced the growth parameters viz., plant height and dry weight of plant. The plant height increased significantly with each increment in the dose up to 60 kg ha^{-1}. However, the difference in plant height due to further increase in the dose of sulphur was not significant. Application of 60 kg S ha^{-1} produced more dry weight of plant at 90 DAS as compared to control and 30 kg S ha^{-1}. Better nutrition to plant resulted in more height and number of branches and other growth parameters, which resulted in higher dry weight of plant. These results are in conformity with those reported by Kumar and Yadav (2007) in mustard.

Sah *et al.,* (2013) reported that application of sulphur resulted into significant variation in the growth characters of mustard. Plant height was significantly improved under 15 kg S ha^{-1} over control and remained unaffected with further increased up to 45 kg S ha^{-1}.

Contrary to this, highest dose of sulphur i.e. 45 kg S ha^{-1} produced higher number of functional leaves, branches and dry matter per plant over control. Maximum LAI was produced with 30 kg S ha^{-1} which was significantly more than 15 kg S ha^{-1} and control.

Rao *et al.,* (2013) reported that application of sulphur significantly increased the plant height. Addition of sulphur at 45 kg ha^{-1} through gypsum recorded the highest plant height. However, it was at par to application of sulphur at 30 kg ha^{-1} through elemental sulphur and sulphur bentonite.

Ray *et al.,* (2014) reported that application of sulphur @ 60 kg S ha^{-1} had significant beneficial effect on various growth parameters of mustard. This treatment was at par with 45 kg S ha^{-1} for plant height at 75 DAS and at harvest and for LAI at 40 DAS. But there were no significant difference among 30, 45 and 60 kg S ha^{-1} in increasing the LAI at 75 DAS, dry matter accumulation at 40 and 75 DAS and number of primary branches $plant^{-1}$. Application of 60 kg S ha^{-1} attained appreciable more crop growth than 20 to 40 kg S ha^{-1}. Dry matter production increased with the age of plant and increase was accelerated between 45 and 90 DAS.

Yield and yield attributes

Piri and Sharma (2006) reported that seed and straw yield increased significantly with increasing level of sulphur up to highest level of 45 kg S ha^{-1}. Application of 15, 30 and 45 kg S ha^{-1} increased the seed yield over the control by 9, 16 and 23%, respectively. All the yield attributes, seeds $siliqua^{-1}$, 1000-seed weight of Indian mustard increased significantly with increasing doses of sulphur up to 45 kg ha^{-1}, however, the differences between 0 and 15 kg S $ha^{-1}$for siliquae $plant^{-1}$ and 1000-seed weight and between 15 and 30 kg S ha^{-1} for seeds $siliqua^{-1}$ and 1000-seed weight were not significant. Jat *et al.,* (2003) also reported an increase in straw yield of Indian mustard with increasing level of sulphur.

Kumar and Yadav (2007) reported that a significant response of crop was observed up to 30 kg S ha^{-1} in seed and stover yields. Application of 30 kg S ha^{-1} produced more number of primary branches at 90 days after sowing as compared to control. Number of siliquae/plant significantly increased up to 30 kg S ha^{-1}. The highest number of siliquae of 334.2/plant was recorded with 45 kg S ha^{-1}. The highest number of seeds/siliqua was recorded at 45 kg S ha^{-1}, which was on a par with that of 30 kg S ha^{-1} and was significantly superior to the control and 15 kg S ha^{-1}. The maximum test weight of 4.63 g/1000 seeds was recorded with 45 kg S ha^{-1} and minimum in control (3.84 g/1000 seeds).

The seed and stover yields were significantly influenced by different sulphur levels. The highest seed yield and stover yield were recorded at 45 kg S ha^{-1}, which were on a par with those of 30 kg S ha^{-1} and these were significantly superior to the control. The increase in the seed yield due to application of 15, 30 and 45 kg S ha^{-1} over control was 20.5, 42.3 and 48.0%, respectively.

Makeen *et al.,* (2008) reported that number of siliqua $plant^{-1}$, number of grains siliqua-weight of 1000 seeds, seed yield and harvest index were significantly influenced by application of sulphur. Application of sulphur @ 60 kg ha^{-1} recorded the highest values with respect to these parameters. The seed yield increased to25.5 q ha^{-1} at 60 kg S ha^{-1} as compared to 11.1 q ha^{-1} at control. These results are in agreement with the findings of Raut *et al.,* (2000), Sharma (1994) and Sarma and Dehnath (1999). Harvest index increased significantly and harvest index at 60 kg S ha^{-1} was higher than other treatments.

Faujdar *et al.,* (2008) reported that sulphur fertilization at 40 kg S ha^{-1} remained at par with 60 kg S ha^{-1} and significantly increased the seed and stover yield to the tune of 26.2 and 12.4% and 18.5 and 8.5%, respectively over control and 20 kg S ha^{-1}. Similar results have been reported by Singh and Kumar (1996).

Kapur *et al.,* (2010) reported that number of primary and secondary branches $plant^{-1}$, number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$ and test weight were recorded significantly higher with 60 kg S ha^{-1} but it was at par with 45 kg S ha^{-1} and 30 kg S ha^{-1} levels in case of number of primary and secondary branches $plant^{-1}$ as well as found at par with 45 kg S ha^{-1} for number of siliqua $plant^{-1}$, no. of seeds $siliqua^{-1}$ and test weight. The significantly higher seed yield was recorded with sulphur @ 60 kg ha^{-1} and higher straw yield was recorded with S fertilization @ 45 kg ha^{-1} which was at par with 60 kg S ha^{-1} and 30 kg S ha^{-1}. The increase in seed yield under S levels at 60, 45, 30 and 15 kg ha^{-1} was 45.0, 44.9, 41.0 and 23.0% over control.

Parmar *et al.,* (2010) reported that the significantly highest number of branches per plant and test weight was recorded with 45 kg

S ha^{-1}. However, the control and 15 kg S ha^{-1} were found at par with each other. These results conformed the findings of Tomar *et al.,* (1996). Application of 45 kg S ha^{-1} recorded significantly the highest seed yield (20.5 q ha^{-1}) which was 61.9, 26.9 and 10.0% higher over control, 15 and 30 kg S ha^{-1}, respectively. The 45 kg S ha^{-1} recorded 30.8, 17.6 and 3.8% higher stover yield over control, 15 and 30 kg S ha^{-1}, respectively. However, the 30 and 45 kg S ha^{-1} levels were statistically at par with each other.

Jyoti *et al.,* (2012) worked at North 24 Parganas, West Bengal on Inceptisol (pH 6.67) observed that the highest seed and stover yield of rapeseed (cv 'B-9') was 910 and 4320 Kg ha^{-1}, respectively found under the application of 30 Kg S ha^{-1} through SSP, resulting in a 41.9 and 18.9% increase in the yield over that of the control during both of the years.

However, the highest benefit: cost (1.77) was recorded with the foliar application of 1% S-52 (liquid fertilizer) at 20 DAS, vegetative growth stage (35 DAS) and pre flowering stage (50 DAS).

Jat *et al.,* (2012) reported that all the yield attributes (siliquae /plant, seeds /siliqua and test weight), yield (seed and stover) increased significantly with increasing rates of sulphurupto 40 kg ha^{-1}. But the biological yield increased significantly upto 60 kg S ha^{-1}. The seed yield increased by 24.8 per cent over no sulphur application. Baudh *et al.,* (2012) reported that productivity increased with increasing level of S. Application of S was highly influenced with the application of 60 kg S ha^{-1} than 20 to 40 kg S ha^{-1}. The productivity such as biomass production, number of capsules, seed output and reproductive capacity with grain biological yield also increased with increasing level of S.

Chattopaddhyay and Ghosh (2012) reported that the increase in grain yield was significant in S treated plots over control but higher S level i.e. 60 kg S ha^{-1} failed to register higher yield increase over that at 45 kg S ha^{-1}. Grain yield of mustard increased significantly with increased levels of S up to 45 kg S ha^{-1}, above which decreasing trend was observed.

Sah *et al.,* (2013) reported that application of sulphur @ 45 kg ha^{-1} increased number of siliquae/plant, test weight, seed yield and straw yield. Fertilization of 45 kg S ha^{-1} produced the highest seed yield of 19.2 q ha^{-1} in comparison to 13.2 q ha^{-1} in control. Rao *et al.,* (2013) reported that sulphur application significantly influenced the yield attributing characters and yield over control regardless of the levels of sulphur.

Debnath *et al.,* (2014) reported from Kalyani (West Bengal) that the seed yield on average was 14.5% higher in elemental S over the control which further increased to 30.6% along with inoculated S oxidizers.

Neha *et al.,* (2014) reported that application of 40 kg S ha^{-1} recorded significantly higher seed yield (19.6 q ha^{-1}) and stover yield (70.9 q ha^{-1}) over 20 kg S ha^{-1} and no sulphur higher to this level remained at par with each other. Application of 40 kg S ha^{-1} gave significantly higher seed and stover yield by registering 12.9 and 13.5% higher over no sulphur. Further, increase in sulphur levels up to 60 kg S ha^{-1} remained at par with above level. Ray *et al.,* (2014) reported that yield of mustard was increased with the increasing dose of S from 0 to 60 kg ha^{-1}. Higher yield was obtained with 60 kg S ha^{-1} resulting in 17.9% increase over control. Singh and Kumar (2014) reported that application of 120 kg N ha^{-1} and 45 kg S ha^{-1} was the best combination for getting higher seed yield, siliquae $plant^{-1}$, siliquae length, number of seed $siliquae^{-1}$and harvest index.

Quality parameter

Oil content

Abdin *et al.,* (2003) observed that the protein content in the seed of mustard can be optimized with the split application of 40 kg S ha^{-1} during the appropriate phenological stages of crop growth and development.

Chandel *et al.,* (2003) reported that the application of 40 kg S ha^{-1} to mustard resulted in significant increase in oil yield of mustard.

Singh and Mukherjee (2004) reported that oil yield of mustard increased with increasing dose of sulphur from 0 to 45 kg S ha^{-1}. However, Sharma *et al.,* (2005).reported that the oil content in mustard increased up to 32.5 kg S ha^{-1}.

Singh *et al.,* (2005) also observed that the oil content in mustard seed significantly increased 6.3% with 60 kg S ha^{-1} over no sulphur application. Piri and Sharma (2006) reported that oil content of mustard increased significantly with increasing level of sulphur up to highest level of 45 kg S ha^{-1}. Application of 15, 30 and 45 kg S ha^{-1} increased the oil content by 13, 22 and 33%, respectively.

Mehdi *et al.,* (2006) conducted a field experiment with 4 levels of sulphur 20, 40, 60 and 80 kg ha^{-1} and reported that oil content in seed of mustard increased with increasing rate of sulphur.

Singh and Singh (2007) reported that each successive increase in the level of sulphur up to 60 kg ha^{-1} significantly increased the oil content of the crop by 36.7% over control.

Singh *et al.,* (2008) reported from Kanpur that the application of 90 kg N and 30 kg S ha^{-1} significantly increased the seed, oil and protein yields, and protein content of seed. The uptake of both N and S by seeds increased with increasing levels of each of the nutrient. Higher doses of N decreased the oil percentage in seed whereas sulphur up to 40 kg ha^{-1} significantly increased it.

Singh *et al.,* (2010) reported that protein content increased with increasing fertility levels and recorded the highest value at 150 % RDF.

Basumatary and Talukdar (2011) observed at, Jorhat, Assam that the highest oil content (41.3%) was obtained due to integration of 60 kg of S with 3.0 t FYM ha^{-1} and resulted in a 12.8% increase in oil content over the control.

Najar *et al.,* (2011) worked at Wadura (Jammu & Kashmir) on clay loam soil and found that the protein content in soybean seeds increased from 34.17 to 37.39 per cent with the increasing levels of sulphur and 35.41 to 36.34 per cent with the increasing levels of boron which was 9.42 and 2.63 per cent higher respectively over the control.

Kumar and Trivedi (2012) reported that the oil content increased significantly with increasing level of sulphur up to highest level of 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} increased the oil content by 7.8, 4.8 and 3.9% over 0, 20 and 40 kg S ha^{-1}, respectively. Pachauri *et al.,* (2012) reported that the oil content recorded less than 90 kg S ha^{-1} were higher by 11.3, 7.4 and 1.5 per cent over 0, 30 and 60 kg S ha^{-1}, respectively.

Sah *et al.,* (2013) reported that application of sulphur @ 45 kg ha^{-1} increased the oil content of mustard. Neha *et al.,* (2014) reported that an application of 40 kg S ha^{-1} significantly enhanced the oil content by 5.0 and 8.7% in comparison to 20 kg S ha^{-1} and no sulphur.

Singh and Kumar (2014) reported that the application of 120 kg N and 45 kg S ha^{-1} was the best combination for getting higher oil content in seed of mustard.

Protein content

Singh and Singh (2005) reported that with the increasing dose of sulphur significantly increased the protein content in seed of mustard.

Mehdi *et al.,* (2006) reported that protein yield increased with increasing rate of sulphur, whereas protein content in seed of mustard was increased with increasing rate of sulphur up to 60 kg ha^{-1} only and it was decreased their after. Kumar and Yadav (2007) reported from Faizabad that the application of 90 kg N and 30 kg S ha^{-1} significantly increased the seed, oil and protein yields, and protein content of seed.

Bhat *et al.,* (2007) studied at Rajouri (Jammu & Kashmir), and found that protein content (23.88%) and oil content (42.90%) in mustard seed were registered higher with the application of 25% FYM N + 75% fertilizer N + 40 kg S ha^{-1} and 50% FYM-N + 50% fertilizer N + 40 kg S ha^{-1} statistically identical to each other and significant difference to the rest of the treatments. Singh *et al.,* (2008) reported from Kanpur that the application of 90 kg N and 30 kg S ha^{-1} significantly increased the seed, oil and protein yields, and protein content of seed. The uptake of both N and S by seeds increased with increasing levels of each of the nutrient. Higher doses of N decreased the oil percentage in seed where assulphur up to 40 kg ha^{-1} significantly increased it.

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Najar *et al.,* (2011) worked at Wadura (Jammu & Kashmir) on clay loam soil and found that the protein content in soybean seeds increased from 34.17 to 37.39 per cent with the increasing levels of sulphur and 35.41 to 36.34 per cent with the increasing levels of boron which was 9.42 and 2.63 per cent higher respectively over the control.

Kumar and Trivedi (2011) reported from Gwalior M.P that the application of 60 kg S ha^{-1} increased the oil content by 7.84, 4.87 and 3.93% over 0, 20 and 40 kg S ha^{-1} respectively. The highest seed protein (23.86%) was recorded due to application of 60 kg S ha^{-1} and decreasing levels of S led to significant decreasing in this bio-chemicals parameter of mustard. Among different sources of sulphur, the highest protein content (22.43%) was observed due to ammonium sulphate followed by pyrite (21.59%), gypsum (21.29%) and SSP (20.86%), respectively.

Nutrient concentration in soil and uptake

Lanjewar *et al.,* (2005) reported that it was found that increasing application of sulphur significantly increased the nutrient uptake and content of S upto 60 kg S ha^{-1}. However, 60 kg S ha^{-1} was better than 20 kg S ha^{-1} in these respects. Thus 60 kg S followed by 40 kg S ha^{-1} appeared to be appropriate doses to increase the uptake.

Piri and Sharma (2006) reported that 30 kg S ha^{-1}, being at par with 15 kg S ha^{-1}, significantly increased sulphur content in seed over no sulphur, whereas sulphur content increased with increasing dose of sulphur up to 30 kg S ha^{-1}. Further increase in the dose of sulphur from 30 to 45 kg S ha^{-1} did not increase sulphur content in seed further.

Singh and Singh (2007) reported that the S content in seed increased significantly with increasing levels of S up to 60 kg ha^{-1}. Application of S increased its content in seeds from 0.40% in control to 0.49% with 60 kg S ha^{-1}. Kumar and Yadav (2007) reported that uptake of S increased with increase in the level of S. Further increase in the dose of S did not result in significant increase in S uptake by the crop. However, the differences were statistically significant only up to 30 kg S ha^{-1}. Application of S also resulted in significant increase in the S uptake over the control only. Its application at 45 kg S ha^{-1} also showed significant S uptake over that of 15 kg S ha^{-1}.

Zizale *et al.,* (2008) reported that the total uptake of S increased significantly with increase in each dose of S up to 45 kg ha^{-1}. The per cent increase in total S uptake was 11.2 and 66.0 over control with application of S at 15, 30 and 45 kg ha^{-1}, respectively. The maximum S uptake (34.5 kg ha^{-1}) was recorded with 45 kg S ha^{-1}. The highest S content in seed was recorded under the highest dose of S at 45 kg ha^{-1}, which was significantly superior to the rest of the treatments. The similar trend was found for S content of straw. The maximum value of 0.49% and 0.40%, respectively was recorded for seed and straw at the highest level of S at 45 kg ha^{-1}. The maximum S uptake by seed was recorded at S45, which was on par with S30 level but significantly superior to rest of the levels.

Yadav *et al.,* (2010) reported that the slight decrease in pH and EC and increase in organic carbon, available nitrogen, phosphorus, potassium and sulphur after harvest of mustard was recorded by application of sulphur @ 40 kg ha^{-1}. Gangwar *et al.,* (2011) conducted a field experiment and found that different levels of sulphur significantly improved the growth, yield as well as uptake of nutrients by seeds and straw of mustard. Seed inoculation with PSB significantly increased yield, uptake by seed and straw and availability of nutrients in soil. Combined effect of 50 kg P2O5 and 40 kg S ha^{-1} with seed inoculation with PSB gave higher seed and straw yield as well as nutrient content in seed and straw which resulted in higher nutrient uptake by mustard grown in loamy sand of North Gujarat.

Chattopaddhyay and Ghosh (2012) reported that S concentration in grain and stover of mustard increased significantly with increasing S levels up to 60 kg S ha^{-1}, irrespective of sources of S. Results indicated that the crop responded to S application since soil was deficient in available S. S concentration in mustard grain and stover due to graded levels of S ranged from 0.69 to 0.89 and 0.18 to 0.36 per cent, respectively. Total S uptake continued to increase with the increase in levels of S irrespective of its source.

Neha *et al.,* (2014) reported that application of 60 kg S ha^{-1} improved concentration of S in seed and stover. Similarly, application of 40 kg S ha^{-1} recorded 13.6 and 38.2% of S over 20kg S ha^{-1} and no sulphur, respectively. However, the further increase in sulphur level was statistically at par with this level. The results are in close conformity with findings of Abraham (2001) and Patel *et al.,* (2009).

Economics

Singh and Singh (2007) reported that net returns increased with the increase in S dose up to 60 kg ha^{-1} and this dose resulted in the highest net returns. The benefit: cost ratio in sulphur fertilizer was 1.75, 1.84 and 1.96 due to application of 20, 40 and 60 kg S ha^{-1}, respectively. Malviya *et al.,* (2007) reported that sulphur application at 60 kg S ha^{-1} was found remunerative by Rs. 483 ha^{-1} over 30 kg S ha^{-1}.

Kumar and Trivedi (2012) reported that the net return (Rs. 25098 ha^{-1}) and benefit: cost ratio (3.73) was recorded at 40 kg S ha^{-1}. This may be because of the difference in yield between 40 and 60 kg S ha^{-1} was at par and cost of cultivation was lesser with 40 kg S ha^{-1}. Pachauri *et al.,* (2012) reported that the highest net return of Rs. 42, 018 was recorded with the application of 90 kg S ha^{-1}. However, B: C ratio of 4.34 was higher at 60 kg S ha^{-1}. Whereas 90 kg S ha^{-1} gave 4.25 followed by 30 kg S ha^{-1} (4.06) and control plot (4.04).

Verma *et al.,* (2012) conducted a field experiment during rabi season of 2008-09 and 2009^{-1}0 at Kanpur to evaluate the effect of sulphur (0, 20, 40 and 60kg S ha^{-1}), zinc (0, 5 and 10 kg Zn ha^{-1}) and boron (0, 0.5 and 1.0 kg B ha^{-1}) levels on quality, economics and uptake of nutrients by mustard [*Brassica juncea* (L.)]. On economic basis, the highest profit was recorded with combined use of 60 kg S +5 kg Zn and 1.0 kg B ha^{-1}.

Sah *et al.,* (2013) reported that application of 45 kg S ha^{-1} gave maximum net return (Rs. 25599 ha^{-1}) which was followed by 30 kg S ha^{-1} (23365 ha^{-1}) and 15 kg S ha^{-1} (Rs. 19221 ha^{-1}) and gave highest maximum B: C ratio of 3.89.

Verma *et al.,* (2012) reported that the application of 60 kg S ha^{-1} gave significantly higher protein content (%) in seed.

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