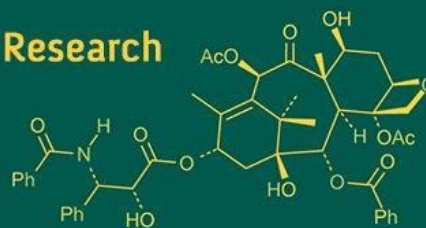


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 423-426
www.biochemjournal.com
Received: 22-05-2025
Accepted: 26-06-2025

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Effect of various levels and sources of sulphur fertilization on yield and yield attributes of mustard (*Brassica juncea* L.)

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DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i8Sg.5189>

Abstract

Sulphur is an important and most critical nutrient for achieving both quantity and quality productions. Therefore, a field study was conducted to see the impact of various levels and sources of sulphur fertilization on yield and yield attributing characters of mustard crop *var.* Pusa Bold. For this purpose, four levels of sulphur doses, 0, 20, 40 and 60 Kg /ha were applied to the mustard crops and three different sources of sulphur were taken for treatments as Bentonite, Single Super Phosphate (SSP), and Ammonium Sulphate. All the treatments were planned under factorial randomised block design (FRBD). However, different parameters were recorded as plant height, no. of siliquae/plant, no. of seed /siliquae, length of siliquae, test weight, seed yield, stover yield and oil content. Whereas, significant response for seed and stover yield was noted under 60 Kg/ha sulphur application *i.e.* 19.60 q/ha and 52.00 q/ha, respectively and minimum yield was recorded for both seed and stover yield under control treatments (0 Kg/ha). As source of fertilizer ammonium sulphate was recorded to have a maximum seed yield (18.76 q/ha) and stover yield (49.28 q/ha). For the quality parameters of mustard oil, content was also tested, which observed higher under 60 Kg/ha (39.65%). The results highlighted that the mustard crop yield was significantly needed sulphur application to achieve quality production in *vertisol* conditions.

Keywords: Mustard, oil content, sulphur source and level

Introduction

Mustard is the second most important edible oilseed crop in the country, after soybean, which account for nearly 30% of the total oilseed production. Globally, rapeseed-mustard production stands at 88.34 million tonnes, cultivated on 42.58 million hectares, with an average productivity of 20.07 quintals per hectare. In the Indian agricultural economy, oilseeds are second only to cereals in terms of area, production, and economic value, contributing about 1.5% to the gross domestic product (GDP) and 8% to the value of all agricultural products (Hegde, 2009) [4]. Oilseeds hold significant value in human nutrition, animal feed, and medicine. Sulphur plays a vital role in the chemical composition and quality of mustard tissues, significantly influencing growth and yield. India cultivated 9.2 million hectares and produced 13.3 million tonnes with having productivity of 14.45 q/ha. In the study area mustard is grown under rice-based cropping systems, typically through broadcasting or line sowing under partially irrigated conditions, covering an area of 36.87 thousand hectares and producing 42.2 thousand metric tonnes, with an average productivity of 11.45 q/ha. Oilseed crops require higher nutritional demand for sulphur compared to cereal crops. While cereals typically absorb around 3-4 kg of sulphur per tonne of grain production and oilseeds like mustard demand as much as 12 kg per tonne. However, most Indian soils are deficient in sulphur which limit crop productivity and quality (Chaurasiya *et al.*, 2019) [2]. Sulphur is closely associated with yield improvement, oil content, quality parameters, and stress resistance. Studies have shown that sulphur application can increase mustard yield by 12-48% under irrigated and 17-24% under rainfed conditions. The role of sulphur in synthesizing essential amino acids (methionine and cysteine), proteins, chlorophyll, glucosinolates, and oils underscores its importance in oilseed nutrition and metabolic functions (Kumar *et al.*, 2018) [6].

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Sulphur can be applied through a range of fertilizers such as ammonium sulphate (24% S), single super phosphate (12% S), gypsum (13-18% S), elemental sulphur (100% S), pyrites (24% S), and others like zinc, magnesium, and copper sulphates. Among these, gypsum, SSP, and ammonium sulphate are more cost-effective and widely accessible. However, these sources vary in solubility, availability, and release patterns in soil, necessitating judicious and efficient use to ensure optimal crop benefits and economic returns. Despite sulphur's well-established importance, there remains a gap in localized information on how different sources and rates of sulphur affect yield performance in oilseed crops, particularly in *Vertisols*. Therefore, this study was undertaken to understand the effect that different sources of sulphur and levels can have on the yield of mustard and its attributing characteristics in *Vertisol* soil conditions.

Materials and Methods

Study area

The study area is situated between 21°23' North latitude and 81°70' East longitude, with an altitude of 296 m above mean sea level. This region fall under dry-moist and sub-humid climatic conditions. However, the area receives rainfall annually ranging from 1200 to 1400 mm. Whereas about 88% of the total rainfall is received during the rainy season which spread from June to September, and the remaining 8% during the winter season from October to February. The mean maximum temperature was noted 23.3 °C to 40.6 °C during the *rabi* season of 2019-2020. The crop was shown in *Vertisol* which was locally known as Kanhar Mitti which characterised clayey in texture containing 20 percent sand, 35 percent silt, and 45 percent clay. However, soil nutrient status was observed as neutral in reaction pH 7.2 and normal EC 0.23 dS/m, whereas available nitrogen, available

phosphorus, available potassium and available sulphur were recorded as 211 Kg/ha, 15.3 Kg/ha, 345.19 Kg/ha and 13.02 kg/ha respectively.

Experiment details

For this experiment, mustard variety pusa bold was sown in three replications of factorial randomized block design (FRBD). Whereas factor A was four-level of sulphur dose *i.e.* 0, 20, 40 and 60 Kg/ha and factor B was three sources of sulphur fertiliser *i.e.* as Bentonite, Single Super Phosphate, and Ammonium Sulphate. All the data related to yield, oil content and yield attributing characters were analysed as per standard procedures.

Results and Discussion

Plant height

The maximum plant height of mustard was recorded as 185.53 cm under 60 Kg/ha sulphur application, and the minimum plant height with 172 cm under 0 Kg/ha sulphur. While the plant height was noted at par with the application of sulphur at 40 Kg/ha (183.22 cm). However, ammonium sulphate was received at maximum plant height (184.34 cm) and lowest was noted as Bentonite application (172.56 cm) as sulphur source. Sulphur plays key role on physiological activities which enhances vigorous root growth, cell multiplication, cell division, elongation and cell expansion in the plant body and imparts a deep green color to leaves due synthesis of chlorophyll meanwhile ultimately increased plant height as also suggested by Singh and Thenua 2016^[10]. Whereas, the application of ammonium sulphate reported higher plant height might be due to present of nitrogen in ammonium sulfate which increase nitrogen availability and its role in the synthesis of chlorophyll and further increase plant height are also found by Kumar *et al.*, 2018^[6].

Table 1: Effect of various levels and sources of sulphur on yield attributes of Mustard.

Treatments	Plant height (cm)	No. of Siliquae /plant	No. of Seed/Siliquae	length of siliquae (cm)	Test weight (1000 seed weight)
Sulphur level					
S ₀	172.00	173.67	9.39	6.03	4.97
S ₂₀	177.38	196.78	10.09	6.23	4.98
S ₄₀	183.22	210.67	11.13	6.88	5.58
S ₆₀	185.53	210.89	11.5	7.06	5.73
SEm±	2.80	3.35	0.29	0.16	0.3
CD (P = 0.05)	8.21	9.83	0.86	0.48	NS
Sulphur Source					
Bentonite	172.56	191.09	10.35	6.40	5.29
SSP	180.42	197.88	10.53	6.46	5.32
Ammonium Sulphate	184.34	204.70	10.71	6.68	5.35
SEm±	3.23	3.87	0.34	0.19	0.07
CD (P = 0.05)	9.48	11.35	NS	NS	NS
Interaction					
SEm±	5.60	6.70	0.59	0.33	0.11
CD (P = 0.05)	NS	NS	NS	NS	NS

Siliquae per plant

The number of siliquae per plant increases significantly with the application of different doses of sulphur. Whereas, the higher number of siliquae recorded (210.89 /plant) under 60 Kg/ha sulphur application and lower was observed in 0 Kg/ha (173.67/ plant) sulphur application, which was at par with 40 Kg/ha (210.67/ plant) sulphur applications. However, ammonium sulphate achieved higher number of siliquae (204.70/ plant) and Bentonite recorded lower number of siliquae *i.e.* 191.09 /plant. Application of sulphur

with increasing dose resulted in an increase in primary and secondary branches of mustard and higher number of siliquae bearing at these organs as also found by Verma *et al.*, 2018^[13]. The highest number of siliquae per plant was ascribed due to application of ammonium sulphate in comparison to SSP and bentonite, which might be attributed due to increased process of tissue differentiation from somatic tissue to reproductive tissue as suggested by Tatarwal *et al.*, 2013^[12].

Seeds per silique

The different doses of sulphur level significantly affects the number of seeds per silique and maximum seed was (11.50/silique) reported under higher dose of sulphur application 60 Kg/ha which was also noted at par with 40 Kg/ha sulphur application (11.13 seed/silique) while the lowest seed was noted under control treatment (0 Kg/ ha sulphur application) i.e. 9.39 seeds / silique. Whereas, the number of seed per silique was on different source of sulphur fertilizer application was found non-significant differences. Application of different level of sulphur increased photosynthetic assimilation aided in net carbon export to sink, greater diversion of photosynthates to sink (silique and seeds) and improved physiological activity of the plants, boosted the partitioning and translocation of photosynthates to the sink, which caused increase number of seed per silique. These results corroborate with the findings of Rakesh and Banik 2016 ^[14].

Length of silique

The Length of silique was significantly affected by dose of sulphur fertilizers and increases with dose of fertilizers. The minimum length of silique was reported under control (6.03 cm) and maximum was noted under 60 Kg/ha sulphur application (7.06 cm) and also at par with 40 Kg/ha sulphur application (6.88 cm). However, the different sources of sulphur fertilizers was not found significant effect on length of silique was also noted.

The probable reason for higher silique length 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 of mustard as also reported by Dhruw *et al.*, 2017 ^[3].

Test weight

The test weight of mustard was not found to be significant neither with different dose of sulphur nor source of sulphur fertilizer but the higher test weight was noted under 60 Kg/ha sulphur application (5.73 g) and application of ammonium sulphate as sulphur source was also noted non-significant but found higher test weight (5.35 g). Similar results were also confirmed by Ahmad *et al.*, 2011 ^[1].

Seed and Stover yield

The seed yield of mustard was increasing significantly with the increasing dose of sulphur fertiliser. However, higher seed yield was received under 60 Kg/ha (19.60 q/ha) sulphur application, which was at par with the 40 Kg/ha (19.29 q/ha), and the minimum seed yield was obtained (15.87 q/ha) under 0 Kg/ha sulphur application. Whereas, the application of ammonium sulphate only increases seed yield significantly than other treatments i.e. (18.76 q/ha). Similarly, maximum stover yield was reported under 60 Kg/ha (52.00 q/ha) sulphur application, and minimum was under the control treatment (42.00 q/ha), which was also noted at par with 40 Kg/ha sulphur application. While the ammonium sulphate increases the maximum stover yield than other treatments, i.e (49.38 q/ha).

Table 2: Effect of various levels and sources of sulphur on the yield and oil content of Mustard.

Treatments	Seed Yield (q/ha)	Stover yield (q/ha)	Oil content (%)
Sulphur level (kg/ha)			
S ₀	15.87	42.00	36.53
S ₂₀	17.42	45.31	38.88
S ₄₀	19.29	49.26	39.61
S ₆₀	19.60	52.00	39.65
SEm±	0.41	1.36	0.68
CD (P = 0.05)	1.19	3.98	1.98
Sulphur Source			
Bentonite	17.19	44.08	38.62
SSP	18.29	48.07	38.80
Ammonium Sulphate	18.76	49.38	38.50
SEm±	0.47	1.57	0.78
CD (P = 0.05)	1.38	4.60	NS
Interaction			
SEm±	0.81	2.72	1.35
CD (P = 0.05)	NS	NS	NS

The seed and stover yield of mustard was increasing due to crop shown cumulative effect on increased yield attributing characters like number of siliques per plant, number of seeds per silique and 1000 seed weight might have resulted in the production of higher grain yield under 60 Kg/ha sulphur application as also suggested by Sipai *et al.*, 2015 ^[11]. The increase in yield with applied sulphur through application of ammonium sulphate could be attributable to a higher concentration of amino acids and amide compounds in the reproductive organs, which altered growth and yield of mustard. Higher dry matter accumulation in the vegetative parts, which resulted higher stover yield. The relationship of yield with growth parameter and yield attributes in the present study is in accordance with the finding of Ray *et al.*, 2015 ^[8].

Oil content

Oil content in mustard was enhanced significantly by the application of different dose of sulphur fertilizers are indicated in Table 2. The low oil content in mustard was reported under control treatment (36.53%) and high was noted in 60 Kg/ha of sulphur application (39.65%). Whereas, 20 Kg/ha and 40 Kg/ha sulphur application was also showed at par with respect to the oil content in mustard crop. The data presented in Table 2 showed that different sources of sulphur failed to exert their significant effect on oil content in seed. The involvement of Sulphur in the biosynthesis of oil could explain the increase in oil content caused by sulphur application. Sulphur is involved in the formation of glucosides and glucosinolates, as well as sulphydryl-linkage and chemical enactment, all of which aid

in biochemical response within the plant and on hydrolysis produces higher amount of oil just as allyl-isothiocyanate, which is responsible for pungency, a quality determinative factor of mustard oil. Similar results were suggested by Kumar and Trivedi, 2012^[7].

Conclusions

The present study clearly demonstrates that sulphur is a critical nutrient influencing the growth, yield, and quality of mustard (*Brassica juncea* L.), particularly in *Vertisol* soil conditions. The application of sulphur significantly improved all major yield attributes, including plant height, number of siliquae per plant, seeds per silique, silique length, and ultimately seed and stover yield, along with oil content in mustard seeds. Among the four sulphur levels (0, 20, 40, and 60 kg/ha) the highest dose of 60 kg/ha consistently resulted in superior performance across all measured parameters and indicating a strong positive response to sulphur fertilization. In terms of sulphur sources, ammonium sulphate proved to be the most effective in enhancing seed yield, stover yield and plant growth, likely due to its nitrogen content, which complements the sulphur in promoting chlorophyll synthesis and overall vegetative growth. However, the source of sulphur had no significant effect on oil content, test weight, or silique length.

The findings confirm that sulphur plays a vital role in mustard production by boosting physiological and biochemical processes that enhance growth, yield, and quality. Specifically, a sulphur dose of 60 kg/ha applied through ammonium sulphate was the most beneficial under the given soil and climatic conditions. This study underscores the importance of optimized sulphur management for improving mustard productivity and recommends the use of 60 kg/ha of sulphur, preferably through ammonium sulphate, to achieve maximum yield and oil content in *Vertisols*. This study helpful for farmers, soil scientist, agronomist and policy makers specially for oilseed production.

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