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Impact of sulphur sources and foliar nutrition on growth and yield of Indian mustard (*Brassica juncea* L.)

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ABSTRACT

A field experiment was conducted during rabi 2025-26 at the Agricultural Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, to study the effect of different sulphur sources and foliar fertilization on growth and yield of mustard (*Brassica juncea* L.). The experiment was laid out in a Factorial Randomized Block Design with three replications, comprising 16 treatment combinations. The fertility levels comprised control and different sulphur sources, while foliar fertilization included control, one spray at 30 and 45 DAS, two sprays at 30 and 55 DAS and three sprays at 30, 45 and 60 DAS. The mustard variety 'RH-749' was sown at a spacing of 30 × 10 cm using a seed rate of 4 kg ha⁻¹ with a recommended dose of fertilizer of 100:80:40 N:P₂O₅:K₂O kg ha⁻¹. The results revealed that growth attributes such as plant height, dry matter accumulation and crop growth rate improved with sulphur application and foliar fertilization. The maximum plant height (227.23 cm) and dry matter accumulation (20.38 g plant⁻¹ at 60 DAS) were recorded with water-soluble sulphur 1%, whereas three foliar sprays recorded the highest plant height (232.35 cm). Yield attributes also showed marked improvement, with water-soluble sulphur 1% recording the highest number of siliqua plant⁻¹ (210.16) and test weight (4.93 g). The highest seed yield (2012 kg ha⁻¹), straw yield (4975 kg ha⁻¹) and biological yield (6987 kg ha⁻¹) were obtained with water-soluble sulphur 1%, while three foliar sprays recorded the highest seed yield (2070 kg ha⁻¹).

Keywords: Sulphur, Water-soluble sulphur, Foliar fertilization, Mustard, Yield attributes, Seed yield

Introduction

Indian mustard (*Brassica juncea* L.) is one of the major oilseed crops of India and plays an important role in meeting the country's edible oil requirement. The seed contains about 38-42% oil and is valued for its nutritional and culinary properties. The crop is well adapted to cool and semi-arid environments and is widely cultivated across the north-western and central parts of India. Rajasthan is the leading producer of rapeseed-mustard in the country, followed by Madhya Pradesh, Haryana, Uttar Pradesh, West Bengal, Gujarat and Assam. During 2024-25, rapeseed-mustard occupied about 86-92 lakh ha with a production of 126.67 lakh tonnes and average productivity of 1461 kg ha⁻¹ in India (GoI, 2025). Rajasthan contributed about 52.03 lakh tonnes from 34.74 lakh ha, with an average productivity of 1498 kg ha⁻¹. However, mustard productivity in the arid and semi-arid regions of Rajasthan is often limited by poor soil fertility, low organic carbon, coarse texture, inadequate moisture retention and multiple nutrient deficiencies. These constraints reduce nutrient availability and efficiency, particularly under moisture-stressed conditions (Choudhary *et al.*, 2021) [1]. Among the essential nutrients, sulphur (S) is particularly important in oilseed crops and is considered the fourth major plant nutrient after nitrogen, phosphorus and potassium. Sulphur is involved in the synthesis of sulphur-containing amino acids, proteins, vitamins, co-enzyme-A and chlorophyll, and plays an important role in enzyme activity, root development and oil synthesis. On an average, about 12 kg S is required to produce one tonne of oilseed (Jamal *et al.*, 2010) [2]. Thus, adequate S nutrition is essential for achieving higher seed yield and improving oil quality in mustard.

Sulphur deficiency is increasingly becoming a concern in intensively cultivated and light-textured soils due to continuous removal of nutrients by crops and limited external inputs. Different S-containing fertilizers, such as elemental sulphur, gypsum and single superphosphate (SSP), are available for correcting S deficiency. Gypsum, containing about 18% S, is particularly relevant to Rajasthan because of its local availability, while SSP provides both phosphorus and sulphur. Hence, selection of an efficient and economical sulphur source is important for sustaining mustard productivity and improving nutrient-use efficiency. In addition to S, balanced application of nitrogen, phosphorus and potassium is essential for optimum crop growth, as these nutrients regulate vegetative development, root growth, photosynthesis, energy metabolism, water relations and reproductive development. Foliar fertilization provides an alternative or supplementary approach for improving nutrient supply during critical crop growth stages. It involves direct application of nutrients to the foliage, enabling relatively rapid absorption and utilization by plants (Nasiri *et al.*, 2010) [3]. Foliar application is particularly useful when nutrient uptake from the soil is restricted by inadequate soil

moisture or unfavorable soil conditions. It also permits application of small quantities of nutrients directly to physiologically active plant tissues and may improve nutrient-use efficiency while minimizing nutrient losses. Foliar feeding during suitable environmental conditions can further enhance nutrient absorption and utilization (Szymanska *et al.*, 2018) [4]. Therefore, the integration of appropriate sulphur fertilization with foliar application of essential nutrients may offer a promising strategy to improve nutrient availability, growth, productivity and quality of Indian mustard under the nutrient- and moisture-constrained conditions of Rajasthan.

Materials and methods

The field experiment was conducted during the *rabi* season of 2025-26 at the Agricultural Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, situated at 26°48'35" N latitude and 75°51'44" E longitude at an altitude of 432 m above mean sea level under semi-arid climatic conditions. During the crop growing period, the mean maximum and minimum temperatures ranged from 19.3 to 32.1 °C and 6.9 to 16.1 °C, respectively, with total rainfall of 61.5 mm and relative humidity ranging from 64.3 to 92.0%. The soil of the experimental site was clay loam in texture, slightly alkaline in reaction (7.6 pH), with organic carbon of 0.35%, available nitrogen of 276.53 kg ha⁻¹, phosphorus of 22.18 kg P₂O₅ ha⁻¹ and potassium of 318.55 kg K₂O ha⁻¹. The experiment was laid out in a Factorial Randomized Block Design with three replications, comprising 16 treatment combinations. The fertility levels comprised control and sulphur application treatments, while foliar application comprised control (no spray), one spray at 30 and 45 DAS, two sprays at 30 and 55 DAS and three sprays at 30, 45 and 60 DAS. The recommended

fertilizer dose was 100:80:40 kg ha⁻¹ N: P₂O₅: K₂O, supplied through urea, DAP and muriate of potash, with sulphur applied as per the respective treatments. The mustard variety 'RH-749' was sown manually at 30 × 10 cm spacing using a seed rate of 4 kg ha⁻¹ in plots of 4.5 × 3.0 m (gross) and 3.8 × 2.4 m (net). Half of the nitrogen and full doses of phosphorus and potassium were applied as basal at sowing, while the remaining nitrogen was applied as top dressing at 35 DAS followed by irrigation. Foliar application of NPK (19:19:19) was carried out at 30, 45 and 60 DAS. Standard agronomic practices such as gap filling, thinning, weeding, irrigation and plant protection measures were carried out as required. Plant stand was recorded at 20 DAS and harvest and expressed as lakh plants ha⁻¹. Plant height was recorded from five randomly selected and permanently tagged plants at 45 DAS and harvest using a metre scale and expressed in cm. Dry matter accumulation was determined from five randomly selected plants at 45 DAS and harvest after sun-drying and oven-drying at 65 °C to constant weight and expressed as g plant⁻¹. Crop growth rate was calculated from the increase in dry matter production per unit area and expressed as g m⁻² day⁻¹, while relative growth rate was calculated and expressed as g g⁻¹ day⁻¹. Number of siliques plant⁻¹ was recorded from five randomly selected plants, while number of seeds silique⁻¹ was determined from 20 randomly selected siliques. Test weight was recorded by weighing 1000 cleaned seeds and expressed in gram. The crop was harvested manually at physiological maturity when about 80 per cent of the siliques turned yellowish-brown. The harvested biomass was sun-dried, weighed, threshed and winnowed, and seed yield was expressed as kg ha⁻¹. Straw yield was calculated by subtracting seed yield from biological yield, while biological yield was expressed as kg ha⁻¹. Harvest index was calculated as the ratio of seed yield to biological yield and expressed as percentage.

Table 1. Effect of different Sulphur sources and foliar fertilization on plant population and plant height of mustard (*Brassica juncea* L.)

Treatments	Plant Population (plants m ⁻¹ row length)	Plant Height (cm)		
	At Harvest	At 60 DAS	At 90 DAS	At Harvest
Fertility levels				
1. Control	22.68	109.59	157.48	173.80
2. S 40 Kg ha ⁻¹ (Gypsum)	22.71	117.02	179.11	204.31
3. S 40 Kg ha ⁻¹ (SSP)	22.87	130.27	201.82	222.25
4. Water soluble sulphur 1%	22.96	133.95	208.34	227.23
SEm±	0.35	2.26	3.45	4.47
CD (P = 0.5)	1.01	6.53	9.96	12.90
Sulphur application				
1. Control - No spray	22.86	108.24	155.86	173.41
2. One spray- at 30 DAS	22.74	117.87	178.56	201.29
3. Two spray -at 30 and 45 DAS	22.85	129.60	197.16	220.54
4. Three spray- at 30, 45 and 60 DAS	22.76	135.12	215.18	232.35
SEm±	0.35	2.26	3.45	4.47
CD (P = 0.5)	1.01	6.53	9.96	12.90
CV (%)	5.32	6.38	6.40	7.48

Table 2. Effect of different Sulphur sources and foliar fertilization on dry matter accumulation and CGR of mustard (*Brassica juncea* L.)

Treatments	Dry matter accumulation (g plant ⁻¹)			CGR	
	At 60 DAS	At 60-90 DAS	At 60-90 DAS	At 60-90 DAS	At 90-Harvest
Fertility levels					
1. Control	15.20	21.45	21.45	21.45	35.65
2. S 40 Kg ha ⁻¹ (Gypsum)	17.15	26.38	26.38	26.38	35.57
3. S 40 Kg ha ⁻¹ (SSP)	18.63	30.21	30.21	30.21	42.14
4. Water soluble sulphur 1%	20.38	30.24	30.24	30.24	43.35
SEm±	0.41	0.75	0.75	0.75	1.16
CD (P = 0.5)	1.19	2.17	2.17	2.17	3.34

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Treatments	Dry matter accumulation (g plant ⁻¹)			CGR	
	At 60 DAS	At 60-90 DAS	At 60-90 DAS	At 60-90 DAS	At 90-Harvest
Sulphur application					
1. Control - No spray	15.38	24.04	24.04	24.04	37.44
2. One spray- at 30 DAS	17.40	26.04	26.04	26.04	37.47
3. Two spray -at 30 and 45 DAS	18.44	29.11	29.11	29.11	40.44
4. Three spray- at 30, 45 and 60 DAS	20.14	29.09	29.09	29.09	41.37
SEm±	0.41	0.75	0.75	0.75	1.16
CD (P = 0.5)	1.19	2.17	2.17	2.17	3.34
CV (%)	7.98	9.59	9.59	9.59	10.21

Table 3. Effect of different Sulphur sources and foliar fertilization on yield attributes of mustard (*Brassica juncea* L.)

Treatments	Number of siliqua plant ⁻¹	Number of seeds siliqua ⁻¹	Test Weight (g)
Fertility levels			
1. Control	153.43	15.79	4.42
2. S 40 Kg ha ⁻¹ (Gypsum)	185.58	17.03	4.49
3. S 40 Kg ha ⁻¹ (SSP)	195.53	22.15	4.77
4. Water soluble sulphur 1%	210.16	21.83	4.93
SEm±	4.56	0.35	0.14
CD (P = 0.5)	13.18	1.02	NS
Sulphur application			
1. Control - No spray	159.66	18.42	4.37
2. One spray- at 30 DAS	180.11	18.92	4.57
3. Two spray -at 30 and 45 DAS	195.13	19.42	4.76
4. Three spray- at 30, 45 and 60 DAS	209.79	20.03	4.92
SEm±	4.56	0.35	0.14
CD (P = 0.5)	13.18	1.02	NS
CV (%)	8.49	6.40	10.34

Results and Discussion

Growth attributes

The application of different sulphur sources and foliar fertilization significantly affected the growth of mustard (Table 1). Plant population at harvest showed only a small variation among treatments, indicating that the treatments had limited influence on crop establishment. In contrast, plant height increased considerably with sulphur application. The maximum plant height at harvest (227.23 cm) was recorded with water-soluble sulphur 1%, compared with 173.80 cm under control. Among foliar treatments, three sprays at 30, 45 and 60 DAS recorded the highest plant height (232.35 cm). The better growth under water-soluble sulphur may be attributed to its rapid availability and efficient sulphur uptake during active growth stages. Sulphur is essential for the synthesis of cysteine, methionine, proteins and enzymes and is closely associated with nitrogen metabolism, chloro-

phyll formation and photosynthetic activity. Thus, adequate sulphur supply may have improved nitrogen assimilation and metabolic activity, resulting in greater plant growth. Similar improvement in plant height and growth of mustard with sulphur application was reported by Kumar *et al.* (2018) [5], Negi *et al.* (2017) [6], Meena *et al.* (2019) [7], Sahoo *et al.* (2017) [8]. Dry matter accumulation also followed a similar trend. Water-soluble sulphur 1% recorded the highest dry matter accumulation at 60 DAS (20.38 g plant⁻¹), while two foliar sprays at 30 and 45 DAS recorded the highest value (18.44 g plant⁻¹) among foliar treatments. The higher biomass production may be due to improved leaf development, photosynthetic activity and greater production and translocation of assimilates. The improvement in crop growth rate further indicates that better nutrient availability supported continuous biomass accumulation during crop growth. Similar beneficial effects of sulphur nutrition on dry matter accumulation and growth rate in mustard were reported by Kumar *et al.* (2018) [5], Meena *et al.* (2019) [7].

Table 4. Effect of different Sulphur sources and foliar fertilization on yield of mustard (*Brassica juncea* L.)

Treatments	Seed yield kg ha ⁻¹	Straw yield kg ha ⁻¹	Biological yield kg ha ⁻¹	Harvest Index
Fertility levels				
1. Control	1284	3775	5059	25.23
2. S 40 Kg ha ⁻¹ (Gypsum)	1533	4016	5549	27.50
3. S 40 Kg ha ⁻¹ (SSP)	1963	4663	6626	29.34
4. Water soluble sulphur 1%	2012	4975	6987	28.47
SEm±	42.90	117.45	123.76	0.68
CD (P = 0.5)	123.91	339.23	357.43	1.97
Sulphur application				

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Treatments	Seed yield kg ha ⁻¹	Straw yield kg ha ⁻¹	Biological yield kg ha ⁻¹	Harvest Index
1. Control - No spray	1217	3985	5202	23.43
2. One spray- at 30 DAS	1481	4314	5795	25.54
3. Two spray -at 30 and 45 DAS	2024	4485	6509	30.93
4. Three spray- at 30, 45 and 60 DAS	2070	4645	6716	30.64
SEm±	42.90	117.45	123.76	0.68
CD (P = 0.5)	123.91	339.23	357.43	1.97
CV (%)	8.75	9.34	7.08	8.57

Yield attributes and yield

Yield attributes were markedly improved by sulphur sources and foliar fertilization (Table 3). Water-soluble sulphur 1% recorded the maximum number of siliqua plant⁻¹ (210.16) and test weight (4.93 g), whereas 40 kg S ha⁻¹ through SSP recorded the highest seeds siliqua⁻¹ (22.15). Among foliar treatments, three sprays at 30, 45 and 60 DAS produced the maximum siliqua plant⁻¹ (209.79) and test weight (4.92 g). The improvement in yield attributes may be attributed to better vegetative growth and greater availability of photosynthates during flowering, siliqua formation and seed filling. Sulphur also plays an important role in protein synthesis and reproductive metabolism, which may have favoured better seed setting and seed development. Similar findings were reported by Meena *et al.* (2018) [9], Kumar *et al.* (2019) [10], Jat *et al.* (2021) [11] and Patel *et al.* (2022) [12]. Seed, straw and biological yields showed a corresponding improvement with better sulphur nutrition (Table 4). Water-soluble sulphur 1% recorded the highest seed yield (2012 kg ha⁻¹), straw yield (4975 kg ha⁻¹) and biological yield (6987 kg ha⁻¹), compared with 1284, 3775 and 5059 kg ha⁻¹, respectively, under control. Among foliar treatments, three sprays at 30, 45 and 60 DAS produced the highest seed yield (2070 kg ha⁻¹) and biological yield (6716 kg ha⁻¹). The higher seed yield appears to be the cumulative result of improved plant height, biomass production and yield attributes, which increased both source capacity and sink development. Timely foliar nutrient supply during active and reproductive stages may have maintained plant nutritional status and supported photosynthesis, assimilate translocation and seed filling. Similar improvement in yield attributes and productivity through foliar fertilization was reported by Choudhary *et al.* (2019) [13], Kumawat *et al.* (2020) [14], Sethi *et al.* (2020) [15], Kumari *et al.* (2021) and Singh *et al.* (2022).

Conclusion

The application of different sulphur sources and foliar fertilization significantly improved the growth and productivity of mustard. Water-soluble sulphur @ 1% recorded better growth, yield attributes and seed yield, while three foliar sprays at 30, 45 and 60 DAS generally performed best. The improvement was mainly due to better sulphur availability, enhanced photosynthetic activity, biomass production and assimilate translocation. Overall, water-soluble sulphur @ 1% with timely foliar fertilization was effective in improving mustard productivity under the experimental conditions.

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