



ISSN Print: 2618-060X
 ISSN Online: 2618-0618
 NAAS Rating (2026): 5.20
 IJRA 2026; 9(9): 1094-1097
www.agronomyjournals.com
 Received: 15-07-2026
 Accepted: 20-08-2026
 Published: 26-09-2026

Shubham Shankar Aloni
 Department of Soil Science,
 College of Agriculture,
 Raichur, UAS, Raichur,
 Karnataka, India

Ravi S
 ICAR-KVK, Hagari, University
 of Agricultural Sciences,
 Raichur, Karnataka, India

Manjunatha Bhanuvally
 Soil science, AEEC, Huvina
 Hadagali, UAS, Raichur,
 Karnataka, India

M V Ravi
 soil science and Extension
 leader, AEEC, Koppal, UAS,
 Raichur, Karnataka, India

Krishnamurthy D
 Senior Scientist (Agronomy),
 AICRP, ICAR-KVK, Hagari,
 UAS, Raichur, Karnataka,
 India

Growth, nutrient uptake and soil nutrient status of sesame (*Sesamum indicum* L.) as influenced by levels and sources of soil applied sulphur in a Vertisol

Shubham Shankar Aloni¹, Ravi S², Manjunatha Bhanuvally³, M V Ravi⁴, Krishnamurthy D⁵

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9o.6652>

ABSTRACT

A field experiment entitled “Performance of sesame (*Sesamum indicum* L.) as influenced by soil application of sulphur in a vertisol” was conducted during Rabi 2025-26 at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur. The experiment was laid out in a split-plot design with three replications, with three sulphur levels (10, 15 and 20 kg S ha⁻¹) in the main plots and three sulphur sources (bentonite sulphur, gypsum and elemental sulphur) in the sub plots. Sulphur level and source both influenced growth and nutrient uptake significantly, whereas the interaction was non-significant. Application of 20 kg S ha⁻¹ recorded the higher plant height (94.18 cm), branches plant⁻¹ (5.83), leaf area plant⁻¹ (11.23 dm²) and leaf area index (2.00) at harvest, along with the higher total uptake of N, P, K and S (78.56, 14.41, 71.88 and 16.04 kg ha⁻¹, respectively). Among the sources, bentonite sulphur recorded the higher plant height (93.94 cm) and total uptake of N, P, K and S (71.38, 13.60, 67.67 and 15.32 kg ha⁻¹, respectively) and gypsum recorded the lower values. Soil pH, EC and organic carbon after harvest were not affected, whereas available N, P₂O₅, K₂O and S were highest at 20 kg S ha⁻¹ (258.60, 35.80, 359.67 kg ha⁻¹ and 15.37 mg kg⁻¹, respectively) and bentonite sulphur left the higher available S (14.47 mg kg⁻¹). Application of 20 kg S ha⁻¹ through bentonite sulphur is therefore suggested for sesame on Vertisols of the Northern Dry Zone of Karnataka.

Keywords: Sesame, Sulphur levels, Sulphur sources, Bentonite sulphur, Nutrient uptake, Vertisol

Introduction

Sesame (*Sesamum indicum* L.), often called the queen of oilseeds, is one of the oldest oilseed crops and its oil is unusually stable against oxidation because of lignans such as sesamin and sesamol. India has the largest area under sesame in the world, 15.31 lakh hectares in 2023-24, but productivity is only 553 kg ha⁻¹, which is attributed to rainfed cultivation, poor soil fertility and inadequate nutrient management (DES, 2024) [1].

Sulphur is the fourth major plant nutrient after N, P and K and is part of cysteine, methionine, proteins, enzymes and chlorophyll. Oilseeds need more of it than cereals and a shortage reduces growth, branching, capsule formation and seed and oil yield (Scherer, 2001). Sulphur deficiency has become widespread in Indian soils, with about 59 per cent of the samples in a national assessment falling in the deficient class (Shukla *et al.*, 2021). Intensive cropping, removal of crop residues and increasing use of sulphur-free fertilizers such as urea and DAP are the main reasons. Deficiency also lowers nitrogen-use efficiency because nitrogen assimilation depends on sulphur.

Vertisols are deep, clay-rich soils of peninsular India. They are generally fertile but can be low in available sulphur where organic carbon is low and fertilization is imbalanced (Gaikwad *et al.*, 2021; Tandon, 2011) [2, 3]. Sulphur sources differ in concentration, solubility and speed of release: gypsum supplies sulphate directly, whereas elemental sulphur has to be oxidised by soil microorganisms before the crop can use it. Location-specific recommendations on the rate and source of sulphur for sesame on Vertisols are still inadequate. The present investigation entitled “Performance of sesame (*Sesamum indicum* L.) as influenced by soil application of sulphur in a Vertisol” was therefore undertaken and this paper reports its effect on growth, nutrient uptake and soil nutrient status.

Material and methods

A field experiment was conducted during Rabi 2025-26 at the Agricultural Research Station (ARS), Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka. The site is located in agro-climatic zone III (Northern Dry Zone) at 16°09' N latitude, 77°29' E longitude and 358 m altitude. The soil was a clayey Vertisol, alkaline in reaction (pH 8.22) and low in organic carbon (3.50 g kg⁻¹), available nitrogen

Corresponding Author:
Shubham Shankar Aloni
 Department of Soil Science,
 College of Agriculture,
 Raichur, UAS, Raichur,
 Karnataka, India

(265.32 kg ha⁻¹), available sulphur (9.80 mg kg⁻¹) and DTPA-zinc (0.36 mg kg⁻¹), with medium available phosphorus (35.23 kg P₂O₅ ha⁻¹) and potassium (369.25 kg K₂O ha⁻¹). Maize was the preceding crop.

The experiment was laid out in a split-plot design with three replications. The main plots carried three sulphur levels (S₁: 10, S₂: 15 and S₃: 20 kg S ha⁻¹) and the sub plots carried three sources (F₁: bentonite sulphur, F₂: gypsum and F₃: elemental sulphur), giving nine treatment combinations. Sulphur was applied basally and incorporated before sowing. Sesame variety Swetha was sown at 30 × 15 cm spacing in gross plots of 5.4 × 3.6 m. Farmyard manure at 5 t ha⁻¹ and the recommended fertilizers at 50:20:20 kg N:P₂O₅:K₂O ha⁻¹ were applied uniformly to all plots, and other agronomic and plant protection practices were followed as recommended.

Five plants were tagged in each net plot and growth parameters were recorded at key stages of the crop. Soil and plant samples were analysed for physico-chemical properties and nutrient content using standard protocols, and nutrient uptake was worked out from nutrient concentration and seed and stalk yield. Data were subjected to ANOVA as per Panse *et al.* (1967) [4], and treatment means were compared at 5 per cent critical difference (CD).

Results and discussion

Plant height, number of branches, leaf area plant⁻¹ and leaf area index increased with each increment of sulphur throughout the crop period and the differences among the three levels were significant at 60 DAS and at harvest (Table 1). At harvest, 20 kg S ha⁻¹ (S₃) recorded a plant height of 94.18 cm, 5.83 branches plant⁻¹, a leaf area of 11.23 dm² plant⁻¹ and a leaf area index of 2.00, against 85.56 cm, 4.67, 8.80 dm² and 1.60 at 10 kg S ha⁻¹ (S₁). Leaf area peaked at 60 DAS (22.17 dm² plant⁻¹ under S₃) and declined towards harvest as the leaves senesced. The better growth at higher sulphur levels can be attributed to the role of sulphur in chlorophyll formation, protein synthesis and enzyme activity, which support cell division, leaf expansion and the development of lateral shoots. The present findings are in agreement with Kumari Priya and Debbarma (2025) [5], Kumawat *et al.* (2025) [6] and Karanam Navya Jyothi *et al.* (2025) [7].

Sulphur source also had a significant effect. Bentonite sulphur (F₁) recorded the taller plants (93.94 cm), the most branches (5.73 plant⁻¹) and the higher leaf area (11.00 dm² plant⁻¹) and leaf area index (1.93) at harvest, whereas gypsum (F₂) recorded the lower values (87.03 cm, 4.60, 8.93 dm² and 1.67, respectively), with elemental sulphur in between; only plant height under elemental sulphur and gypsum was on par at harvest. The superior growth under bentonite sulphur may be attributed to a more sustained release of sulphur over the crop period, whereas gypsum supplies sulphate that is available early but can run short by the time of peak demand. Similar superiority of bentonite sulphur over gypsum in sesame was reported by Karanam Navya Jyothi *et al.* (2025) [7] and Ramakrishna (2013) [8]. The interaction was non-significant for all growth parameters, although S₃F₁ recorded the numerically higher values at harvest (96.80 cm, 6.30 branches, 12.40 dm² and 2.20, respectively).

Nutrient concentration in seed and stalk and total uptake of N, P, K and S increased significantly with each increase in sulphur level (Table 2). Total uptake at 20 kg S ha⁻¹ was 78.56, 14.41, 71.88 and 16.04 kg ha⁻¹ of N, P, K and S, compared with 50.43, 8.98, 42.76 and 10.20 kg ha⁻¹ at 10 kg S ha⁻¹. Nitrogen showed the larger response. Seed nitrogen rose from 3.35 to 3.97 per cent and total N uptake rose by 28.13 kg ha⁻¹ while S uptake rose by 5.84 kg ha⁻¹. This points to the close link between the two nutrients, since cysteine and methionine are needed to convert absorbed nitrogen into protein. Part of the increase in uptake also came from the larger seed and stalk yields under higher sulphur (Table 2). Similar increases in nutrient uptake with sulphur were reported by Niharika *et al.* (2025) [9] and Yadav *et al.* (2025) [10] and Jhansi *et al.* (2024) [11] likewise recorded higher phosphorus uptake.

Bentonite sulphur recorded the higher total uptake of N, P, K and S (71.38, 13.60, 67.67 and 15.32 kg ha⁻¹), followed by elemental sul-

phur (64.62, 11.85, 56.68 and 12.98 kg ha⁻¹) and gypsum (56.59, 9.68, 46.90 and 10.85 kg ha⁻¹) and the three sources differed significantly for all four nutrients. Both higher concentration in seed and stalk and larger biomass contributed to this and the result is consistent with the slower release of sulphur from bentonite. Kumar *et al.* (2018) [12] reported higher sulphur content and uptake with bentonite sulphur than with gypsum in mustard and Prusty *et al.* (2024) [13] found that the source of sulphur influenced nutrient uptake in sesame. The interaction was non-significant and S₃F₁ recorded the numerically higher total uptake of N, P, K and S (87.29, 16.40, 83.34 and 18.50 kg ha⁻¹). Soil pH (8.12-8.19), EC (2.13-2.18 dS m⁻¹) and organic carbon (3.37-3.45 g kg⁻¹) after harvest were not significantly affected by sulphur level, source or their interaction, which can be explained by the buffering capacity of the clay soil and the small quantity of sulphur applied in a single season. Available N, P₂O₅ and K₂O increased with sulphur level (Table 3). Twenty kg S ha⁻¹ recorded 258.60, 35.80 and 359.67 kg ha⁻¹, significantly more than 15 kg S ha⁻¹ (250.60, 34.43 and 346.00 kg ha⁻¹), which was on par with 10 kg S ha⁻¹. Sources did not differ significantly in available N and K and bentonite sulphur (35.90 kg P₂O₅ ha⁻¹) exceeded gypsum (33.40 kg P₂O₅ ha⁻¹) only for phosphorus. The gain at higher sulphur may be linked to better root growth, greater residue returns and nutrient cycling and similar improvements in soil nutrient availability with sulphur were reported by Bhardwaj *et al.* (2025) [14] and Khandare *et al.* (2024) [15].

Available sulphur after harvest increased significantly at each level, from 11.73 mg kg⁻¹ at 10 kg S ha⁻¹ to 13.13 and 15.37 mg kg⁻¹ at 15 and 20 kg S ha⁻¹ and it was higher under bentonite sulphur (14.47 mg kg⁻¹) compared with elemental sulphur (13.13 mg kg⁻¹) and gypsum (12.63 mg kg⁻¹), the last two being on par. All the treatments, including S₁F₂ (10.80 mg kg⁻¹), finished above the initial 9.80 mg kg⁻¹, which may benefit the following crop. Raja *et al.* (2007) [16] also reported higher post-harvest available sulphur at higher rates of application. DTPA-extractable Zn, Mn and Cu increased significantly with sulphur level and were highest under bentonite sulphur (0.76, 10.49 and 1.03 mg kg⁻¹, respectively), whereas Fe was not affected. Since bulk soil pH did not change, the increase may be related to changes in soil nutrient dynamics and greater root activity under adequate sulphur supply. Mohanty *et al.* (2019) [17] reported higher DTPA-Zn with sulphur application. The interaction was non-significant for all soil parameters, with S₃F₁ recording the numerically highest available N, P₂O₅, K₂O and S (265.20, 38.10, 364.40 kg ha⁻¹ and 16.40 mg kg⁻¹).

Conclusion

Soil application of sulphur improved growth, nutrient uptake and post-harvest available nutrient status of sesame on a sulphur-deficient *Vertisol*. Growth and total uptake of N, P, K and S increased significantly up to 20 kg S ha⁻¹, the highest level tested, and bentonite sulphur was superior to elemental sulphur and gypsum for most of the parameters studied. Soil pH, EC and organic carbon were not affected. The interaction was non-significant, so the effects of level and source were additive, and 20 kg S ha⁻¹ through bentonite sulphur (S₃F₁) recorded the numerically highest values. Because the response had not levelled off at 20 kg S ha⁻¹, higher rates deserve testing over more seasons and locations.

Acknowledgement

This research was a part of M.Sc. thesis and the author greatly appreciates the research facilities and support provided by the College of Agriculture, Raichur, for conducting this study. The author is grateful to the members of the advisory committee, Major advisor Dr. Ravi S, Senior Soil Scientist, ICAR-KVK, Hagari and members Dr. M V Ravi, Professor, soil science and Extension leader, AECC, Koppal, Dr. Manjunatha Bhanuvally, Associate Professor, Soil science, AECC, Huvina Hadagali and Dr. Krishnamurthy D, Senior Scientist (Agronomy), AICRP, ICAR-KVK, Hagari, for their invaluable guidance, constant encouragement, kind support and constructive sugges-

tions throughout the investigation and in the preparation of this manuscript.

Table 1. Growth parameters of sesame at 60 DAS and at harvest as influenced by levels and sources of sulphur

Treatment	Plant height (cm)		Branches plant ⁻¹		Leaf area plant ⁻¹ (dm ²)		Leaf area index	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Main plot: Sulphur levels (S)								
S ₁ : 10 kg S ha ⁻¹	73.16	85.56	3.47	4.67	19.00	8.80	1.65	1.60
S ₂ : 15 kg S ha ⁻¹	75.93	90.86	4.07	5.17	20.50	10.00	1.95	1.80
S ₃ : 20 kg S ha ⁻¹	80.20	94.18	4.67	5.83	22.17	11.23	2.15	2.00
S.E.m ±	0.85	0.99	0.03	0.03	0.09	0.06	0.02	0.02
C.D. at 5%	2.34	3.03	0.10	0.12	0.36	0.23	0.09	0.08
Sub plot: Sulphur sources (F)								
F ₁ : Bentonite sulphur	80.63	93.94	4.57	5.73	22.00	11.00	2.02	1.93
F ₂ : Gypsum	73.33	87.03	3.63	4.60	19.17	8.93	1.82	1.67
F ₃ : Elemental sulphur	77.00	89.65	4.00	5.33	20.50	10.10	1.92	1.80
S.E.m ±	1.04	1.27	0.03	0.03	0.12	0.06	0.03	0.03
C.D. at 5%	3.12	3.85	0.08	0.10	0.38	0.19	0.10	0.10
Interaction (S × F)								
S ₃ F ₁ (numerically highest)	85.50	96.80	5.10	6.30	23.50	12.40	2.25	2.20
S ₁ F ₂ (numerically lowest)	69.50	81.70	3.10	4.10	18.00	8.00	1.55	1.50
S.E.m ±	2.32	2.73	0.04	0.05	0.19	0.11	0.05	0.05
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Note:

• S₁: 10 kg S ha⁻¹; S₂: 15 kg S ha⁻¹; S₃: 20 kg S ha⁻¹. F₁: bentonite sulphur; F₂: gypsum; F₃: elemental sulphur. Sulphur was applied basally and incorporated before sowing.

• DAS: days after sowing; NS: non-significant. Plant height and branches at 90 DAS were the same as at harvest.

Table 2. Seed yield, stalk yield and total nutrient uptake by sesame as influenced by levels and sources of sulphur

Treatment	Yield (kg ha ⁻¹)		Total nutrient uptake (kg ha ⁻¹)			
	Seed	Stalk	N	P	K	S
Main plot: Sulphur levels (S)						
S ₁ : 10 kg S ha ⁻¹	932.26	2340.00	50.43	8.98	42.76	10.20
S ₂ : 15 kg S ha ⁻¹	1027.06	2450.00	63.60	11.76	56.61	12.93
S ₃ : 20 kg S ha ⁻¹	1113.33	2580.00	78.56	14.41	71.88	16.04
S.E.m ±	11.64	26.77	0.84	0.17	0.83	0.18
C.D. at 5%	35.83	85.11	3.31	0.66	3.24	0.60
Sub plot: Sulphur sources (F)						
F ₁ : Bentonite sulphur	1083.66	2556.66	71.38	13.60	67.67	15.32
F ₂ : Gypsum	971.93	2370.00	56.59	9.68	46.90	10.85
F ₃ : Elemental sulphur	1020.33	2443.33	64.62	11.85	56.68	12.98
S.E.m ±	17.76	34.85	1.11	0.20	0.97	0.22
C.D. at 5%	54.74	102.02	3.41	0.61	3.00	0.68
Interaction (S × F)						
S ₃ F ₁ (numerically highest)	1185.00	2680.00	87.29	16.40	83.34	18.50
S ₁ F ₂ (numerically lowest)	890.60	2250.00	44.24	7.60	35.06	8.48
S.E.m ±	30.77	54.21	1.92	0.34	1.69	0.38
C.D. at 5%	NS	NS	NS	NS	NS	NS

Note:

• S₁: 10 kg S ha⁻¹; S₂: 15 kg S ha⁻¹; S₃: 20 kg S ha⁻¹. F₁: bentonite sulphur; F₂: gypsum; F₃: elemental sulphur. Sulphur was applied basally and incorporated before sowing.

• NS: non-significant. Uptake was computed from nutrient concentration in seed and stalk and the respective yields.

• NS: non-significant. Soil pH, EC, organic carbon and DTPA-Fe were not significantly influenced by any treatment. Initial available S was 9.80 mg kg⁻¹.

Table 3. Post-harvest available nutrients and DTPA-extractable micronutrients in soil as influenced by levels and sources of sulphur

Treatment	Available nutrients				DTPA-extractable (mg kg ⁻¹)		
	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)	S (mg kg ⁻¹)	Zn	Mn	Cu
Main plot: Sulphur levels (S)							
S ₁ : 10 kg S ha ⁻¹	247.93	33.53	344.77	11.73	0.62	9.50	0.93
S ₂ : 15 kg S ha ⁻¹	250.60	34.43	346.00	13.13	0.69	10.18	1.00
S ₃ : 20 kg S ha ⁻¹	258.60	35.80	359.67	15.37	0.77	10.73	1.05
S.Em ±	2.03	0.37	3.58	0.15	0.01	0.11	0.01
C.D. at 5%	6.32	1.06	10.07	0.50	0.03	0.44	0.04
Sub plot: Sulphur sources (F)							
F ₁ : Bentonite sulphur	256.50	35.90	353.13	14.47	0.76	10.49	1.03
F ₂ : Gypsum	248.57	33.40	347.17	12.63	0.64	9.73	0.95
F ₃ : Elemental sulphur	252.07	34.47	350.13	13.13	0.68	10.19	1.00
S.Em ±	4.43	0.60	6.16	0.23	0.01	0.18	0.02
C.D. at 5%	NS	1.85	NS	0.72	0.04	0.54	0.05
Interaction (S × F)							
S ₃ F ₁ (numerically highest)	265.20	38.10	364.40	16.40	0.85	11.20	1.10
S ₁ F ₂ (numerically lowest)	245.80	32.90	342.90	10.80	0.58	9.30	0.90
S.Em ±	7.67	1.04	10.67	0.40	0.02	0.31	0.03
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

Note:

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How to cite this article: Aloni SS, S R, Bhanuvally M, Ravi MV, D K. Growth, nutrient uptake and soil nutrient status of sesame (*Sesamum indicum* L.) as influenced by levels and sources of soil applied sulphur in a Vertisol. *International Journal of Research in Agronomy.* 2026;9(9):1094-1097. doi: <https://www.doi.org/10.33545/2618060X.2026.v9.i9o.6652>