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Integrated Use of Organic Manures and Sulphur for Improving Soil Fertility, Yield and Economics of Sesame (*Sesamum indicum* L.) under Semi-Arid Conditions

Ritik Bhardwaj [a++], Indra Raj Yadav [a#*], A. S. Shekhawat [b†], L. S. Dhayal [b†], Deependra Kumar Saini [c#], Hansraj Shivran [d#] and Manoj Bundela [e#]

[a] *Department of Soil Science, School of Agriculture, Suresh Gyan Vihar University, Jaipur-302017, India.*
[b] *Department of Genetics & Plant Breeding, School of Agriculture, Suresh Gyan Vihar University, Jaipur-302017, India.*
[c] *Department of Entomology, School of Agriculture, Suresh Gyan Vihar University, Jaipur-302017, India.*
[d] *Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur-302017, India.*
[e] *Department of Horticulture, School of Agriculture, Suresh Gyan Vihar University, Jaipur-302017, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *M. Sc. Student;*
[#] *Assistant Professor;*
[†] *Professor;*
**Corresponding author: E-mail: indrarajyadav100@gmail.com;*

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Original Research Article

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ABSTRACT

A field experiment was conducted during *Kharif* season of 2024-25 at Agricultural Research Farm, Department of Soil Science, School of Agriculture Suresh Gyan Vihar University, Jaipur (Rajasthan) to evaluate the effect of organic manures and sulphur on growth, yield, soil fertility, and economics of crop production. The treatments included combinations of vermicompost (2.5 t ha^{-1}), farmyard manure (10 t ha^{-1}),), and sulphur (0, 10, and 20 kg ha^{-1}). Results revealed that the application of vermicompost (2.5 t ha^{-1}) + sulphur (20 kg ha^{-1}) (T8) significantly improved plant height (119.36 cm), number of capsules per plant (69.52), seeds per capsule (60.68), test weight (3.25 g), and grain yield (885.36 kg ha^{-1}). This treatment also resulted in enhanced soil organic carbon (0.48%), available N (164.36 kg ha^{-1}), P (16.85 kg ha^{-1}), K (199.32 kg ha^{-1}), and S (12.36 kg ha^{-1}), along with reduced bulk density (1.31 Mg m^{-3}). Economically, T8 recorded the highest net return (₹44,409 ha^{-1}) and benefit-cost ratio (2.12). The study concludes that the integrated use of vermicompost and sulphur is a viable strategy for improving crop productivity, soil health, and farm profitability under sustainable agricultural practices.

Keywords: Vermicompost; Sulphur; organic manures; soil fertility; crop yield; bulk density; nutrient availability; benefit-cost ratio.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.), often referred to as the "Queen of Oilseeds," is one of the oldest cultivated oilseed crops, with a history spanning over 5,000 years. (Anjum et al*.,* 2024). The adaptability of sesame to harsh Agro-climatic conditions, including drought, high temperatures, and marginal soils, makes it especially suitable for rainfed agriculture in arid and semi-arid regions. This resilience has earned sesame the reputation of a "survivor crop," capable of thriving in environments where other crops fail, such as drylands and areas with erratic rainfall. India stands among the largest producers globally, benefiting from its diverse agro-ecological zones that support sesame cultivation during both kharif and summer seasons (Directorate of Economics and Statistics, 2024).

Rajasthan plays a pivotal role in Indian sesame production, particularly in its rainfed arid and semi-arid zones, where soil fertility is a major constraint due to sandy textures, low organic matter, and nutrient leaching (Vinod 2020). To address these challenges, integrating organic manures such as farmyard manure (FYM), vermicompost, and poultry manure with proper nutrient management is crucial for improving soil health, nutrient availability, and crop productivity (Kumar and Patel, 2022). Organic amendments improve soil structure, moisture retention, microbial activity, and gradual nutrient release, supporting sustained sesame growth under water-limited conditions (Vinod 2020).

Sulphur (S) is recognized as the fourth essential nutrient after N, P, and K, playing a vital role in oilseed crops by influencing protein synthesis, oil content, and enzymatic functions. Sesame, in particular, has a high sulphur requirement, yet soils in Rajasthan often lack sufficient sulphur due to leaching and minimal fertilizer application, leading to yield and quality reductions (Singh 2022). Studies have demonstrated that applying sulphur at 20–40 kg/ha enhances seed yield, oil content, and nutrient use efficiency, especially when combined with organic manures (Mehmood et al., 2021).

The aim of this study is to investigate the effect of integrated nutrient management, specifically the combined application of organic manures and sulphur, on the growth, yield, and quality of sesame grown under rainfed arid and semi-arid conditions of Rajasthan. The objectives include evaluating the impact of different organic manures such as farmyard manure, vermicompost, and poultry manure on soil fertility and sesame productivity; determining the optimal sulphur dose to enhance seed yield and oil content; and assessing the synergistic effects of sulphur and organic amendments on nutrient use efficiency. Additionally, the study seeks to analyse the changes in soil physical and microbial properties resulting from these nutrient management practices and to improve sesame's resilience to moisture stress and poor soil fertility through integrated nutrient application.

2. MATERIALS AND METHODS

A field experiment was conducted during the *Kharif* season of 2024–25 at the Agricultural Research Farm, Department of Soil Science, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan. The experimental site is located in a semi-arid, subtropical climate characterized by extreme temperature variations, with hot and dry summers (maximum temperature up to 45°C) and cold winters (minimum temperature as low as 2.8°C). The area receives an average annual rainfall of 500–800 mm, mostly concentrated during the monsoon season. The collected data were statistically analysed using analysis of variance (ANOVA) appropriate for the RBD design to determine the significance of treatment effects and 9 treatments combination viz., T_0- Control + S (0 kg) T_1- Control + S (10 kg/ha), T_2- Control + S (20 kg/ha), T_3- FYM (10 t ha^{-1}) + S (0 kg), T_4- FYM (10 t ha^{-1}) + S (10 kg/ha), T_5- FYM (10 t ha^{-1}) + S (20 kg/ha), T_6- Vermicompost (2.5 t ha^{-1}) + S (0 kg), T_7- Vermicompost (2.5 t ha^{-1}) + S (10 kg/ha) and T_8- Vermicompost (2.5 t ha^{-1}) + S (20 kg/ha). The soil of the experimental field was sandy loam in texture, saline in reaction, with the following initial characteristics: Soil of the experimental field was sandy loam in texture, saline in reaction with a pH value of 7.62, EC (0.48 dSm^{-1}), poor in organic carbon (0.34%), low in available nitrogen (134.25 kg/ha), phosphorus (13.25kg/ha) and (178.15 kg/ha) but medium in available potassium (320 kg/ha). The sesamum variety 'RT-346-was used in the experiment. Other agronomic practices such as irrigation, weeding, and pest management were uniformly followed across all treatments to ensure optimum crop growth. Soil samples were collected before sowing and after harvest to evaluate changes in soil fertility status.

3. RESULTS AND DISCUSSION

3.1 Crop Study

3.1.1 Growth parameters

The tallest plants were recorded in T_8 – Vermicompost (2.5 t ha^{-1}) + S (20 kg ha^{-1}) (119.36 cm), which was statistically at par with T_7, T_5, and T_6, recording heights of 117.00, 115.62, and 114.32 cm, respectively. The shortest plants were observed in the control (T_0) (98.36 cm). The increase in plant height with vermicompost and sulphur application can be attributed to improved nutrient availability and soil structure (Yadav et al., 2020). Vermicompost enhances microbial activity and nutrient uptake, while sulphur plays a key role in protein synthesis and enzyme activation, contributing to better vegetative growth (Sultana et al., 2020).

3.1.2 Yield parameters

The application of organic manures in combination with sulphur significantly influenced yield and yield-attributing traits. The maximum number of capsules per plant was recorded in T_8 – Vermicompost (2.5 t ha^{-1}) + S (20 kg ha^{-1}) (69.52), which was statistically at par with T7 (66.58). The lowest number was recorded in the control (T_0) (55.32). Similarly, the number of seeds per capsule was highest in T_8 (60.68), followed closely by T7, T5, and T6 (58.45, 56.88, and 55.85), while the lowest was in T_0 (45.32).

In terms of seed quality, the maximum test weight was observed in T_8 (3.25 g), statistically similar to T_7 (3.21 g) and T_6 (3.18 g), while the lowest test weight was recorded in T_0 (2.89 g). The highest grain yield was also recorded in T8 (885.36 kg ha^{-1}), followed by T_7, T_5, and T_6 (845.75, 800.36, and 790.52 kg ha^{-1}, respectively), with T_0 yielding the least (620.12 kg ha^{-1}).

The improved performance of vermicompost-based treatments can be attributed to enhanced soil fertility, better microbial activity, and improved nutrient availability, especially nitrogen and sulphur, which are vital for reproductive growth and seed development (Sultana et al., 2020; Yadav et al., 2020). Sulphur application further supports protein synthesis and enzyme functions, contributing to better capsule formation and seed filling (Sharma et al., 2018). These results affirm the positive synergistic effect of vermicompost and sulphur on crop productivity.

3.2 Soil Analysis

Application of organic manures significantly influenced soil bulk density. The lowest bulk density was recorded in T_8 – Vermicompost (2.5 t ha^{-1}) + S (20 kg ha^{-1}) (1.31 Mg m^{-3}), followed closely and statistically at par with T_7, T_6, and T_5

(1.33, 1.34, and 1.35 Mg m^{-3}, respectively). The highest bulk density was observed in the control (T_0) (1.45 Mg m^{-3}). This reduction in bulk density under organic treatments may be attributed to improved soil structure and increased organic matter content, which enhances soil porosity and reduces compaction (Ghosh et al., 2012).

Soil pH and electrical conductivity (EC) were not significantly affected by organic manure and sulfur application, indicating that these amendments had a neutral effect on the soil's acid-base and salinity status within the study period.

3.3 Soil Chemical Properties

A significant improvement in soil organic carbon (OC) was observed under organic treatments. The highest OC content was recorded in T_8 (0.48%), closely followed by T_7, T_6, and T_5 (0.46%, 0.45%, and 0.44%), while the lowest was in T_0 (0.38%). The increase in OC with vermicompost and FYM may be due to the direct addition of organic residues and stimulation of microbial biomass (Kundu et al., 2022).

Similarly, available nitrogen (N) was maximized in T_8 (164.36 kg ha^{-1}), and remained significantly higher in T_7, T_6, and T_5 (162.25, 160.74, and 159.85 kg ha^{-1}) than in the control (T_0) (143.65 kg ha^{-1}). Organic manures release nitrogen slowly and improve soil microbial activity, enhancing nitrogen mineralization (Sultana et al., 2020).

Available phosphorus (P) was also significantly higher in T_8 (16.85 kg ha^{-1}), followed by T_7, T_6, and T_5 (16.25, 15.85, and 15.68 kg ha^{-1}), compared to T_0 (14.02 kg ha^{-1}). The increase may be attributed to the solubilizing effect of organic acids produced during organic matter decomposition (Lokhande 2022).

Likewise, available potassium (K) peaked in T_8 (199.32 kg ha^{-1}) and was comparable to T_7, T_6, and T_5 (197.15, 196.02, and 194.32 kg ha^{-1}), whereas T0 recorded the lowest (182.36 kg ha^{-1}). Organic amendments improve K availability by reducing fixation and enhancing microbial release of potassium from minerals.

The available sulphur (S) content was significantly improved under treatments receiving external sulphur sources. The highest S content was recorded in T_8 (12.36 kg ha^{-1}), followed by T_7 (11.20 kg ha^{-1}) and T_5 (10.25 kg ha^{-1}), while T_0 recorded the lowest value (7.25 kg ha^{-1}). This highlights the direct effect of sulphur application and the synergistic role of organic manures in enhancing sulphur retention and availability (Kumar et al., 2020).

3.4 Economics

The economic evaluation of treatments revealed significant differences in cost-effectiveness across nutrient management practices. The maximum cost of cultivation was observed in T_8 – Vermicompost (2.5 t ha^{-1}) + S (20 kg ha^{-1}) (₹39,700/ha), closely followed by T_7 and T_6 (₹39,100 and ₹38,500/ha, respectively), primarily due to the higher cost of vermicompost and sulphur inputs. The lowest cultivation cost was recorded in the control (T_0) (₹26,000/ha), which lacked any external input.

Despite higher input costs, the gross return was highest in T_8 (₹84,109/ha), followed by T_7 and T_5 (₹80,346 and ₹76,034/ha), mainly due to increased grain yield under these treatments. The lowest gross return was from T_0 (₹47,511/ha).

Accordingly, net returns were also maximized in T_8 (₹44,409/ha), with T_7 and T_5 yielding ₹41,246 and ₹38,834/ha, respectively. The minimum net return was from T_0 (₹21,511/ha), indicating the inefficiency of non-fertilized control in maximizing profitability.

The highest Benefit: Cost (B:C) ratio was achieved in T8 (2.12), indicating over double returns per rupee invested. This was closely followed by T_7 (2.05) and T5 (2.04). The lowest B:C ratio was in T_0 (1.83), highlighting the economic advantage of integrated nutrient management practices.

These results align with earlier findings that organic manures, particularly vermicompost, though more expensive initially, significantly improve yield and profitability when supplemented with balanced nutrients like sulphur (Yadav et al., 2020; Devi et al., 2025). Vermicompost enhances soil fertility, crop productivity, and nutrient-use efficiency, ultimately leading to better economic returns (Bharadwaj et al. 2021).

Table 1. Effect of organic manures and sulphur on growth and yield attributes

Treatments	Plant height (cm)	Number of capsules plant^{-1}	Number of seed per capsule	Test weight (g)	Grain yield (kg/ha)
T_0- Control + S (0 kg)	98.36	55.32	45.32	2.89	620.12
T_1- Control + S (10 kg/ha)	104.63	59.45	49.52	2.95	535.25
T_2- Control + S (20 kg/ha)	106.52	60.65	51.63	2.98	575.65
T_3- FYM (10 t ha^{-1}) + S (0 kg)	110.32	62.45	54.32	3.00	755.20
T_4- FYM (10 t ha^{-1}) + S (10 kg/ha)	112.65	63.58	55.25	3.08	785.78
T_5- FYM (10 t ha^{-1}) + S (20 kg/ha)	115.62	65.36	56.88	3.12	800.36
T_6- Vermicompost (2.5 t ha^{-1}) + S (0 kg)	114.32	64.85	55.85	3.18	790.52
T_7- Vermicompost (2.5 t ha^{-1}) + S (10 kg/ha)	117.00	66.58	58.45	3.21	845.75
T_8- Vermicompost (2.5 t ha^{-1}) + S (20 kg/ha)	119.36	69.52	60.68	3.25	885.36
S. Em. ±	2.21	1.54	1.68	0.03	32.92
CD%	6.62	4.62	5.03	0.09	98.71

Table 2. Effect of organic manures and sulphur on on soil properties after harvest of sesamum

Treatments	Bulk density (Mg/m^3)	pH	EC (dSm^{-1})	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
T_0- Control + S (0 kg)	1.45	7.65	0.49	0.38	143.65	14.02	182.36
T_1- Control + S (10 kg/ha)	1.42	6.96	0.48	0.39	146.85	14.25	184.45
T_2- Control + S (20 kg/ha)	1.40	7.61	0.48	0.40	148.65	14.65	185.85
T_3- FYM (10 t ha^{-1}) + S (0 kg)	1.38	7.60	0.46	0.42	154.68	15.12	190.32
T_4- FYM (10 t ha^{-1}) + S (10 kg/ha)	1.36	7.59	0.45	0.43	157.78	15.45	192.25
T_5- FYM (10 t ha^{-1}) + S (20 kg/ha)	1.35	7.60	0.43	0.44	159.85	15.68	194.32
T_6- Vermicompost (2.5 t ha^{-1}) + S (0 kg)	1.34	7.57	0.44	0.45	160.74	15.85	196.02
T_7- Vermicompost (2.5 t ha^{-1}) + S (10 kg/ha)	1.33	7.56	0.42	0.46	162.25	16.25	197.15
T_8- Vermicompost (2.5 t ha^{-1}) + S (20 kg/ha)	1.31	7.54	0.40	0.48	164.36	16.85	199.32
S. Em. ±	0.01	0.14	0.02	0.01	1.50	0.46	2.01
CD%	0.04	NS	NS	0.04		1.38	6.01

Table 3. Effect of organic manures and sulphur on economics

Treatments	Total cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
T_0- Control + S (0 kg)	26000	47511	21511	1.83
T_1- Control + S (10 kg/ha)	26600	50849	24249	1.91
T_2- Control + S (20 kg/ha)	27200	54687	27487	2.01
T_3- FYM (10 t ha^{-1}) + S (0 kg)	36000	71744	35744	1.99
T_4- FYM (10 t ha^{-1}) + S (10 kg/ha)	36600	74649	38049	2.04
T_5- FYM (10 t ha^{-1}) + S (20 kg/ha)	37200	76034	38834	2.04
T_6- Vermicompost (2.5 t ha^{-1}) + S (0 kg)	38500	75099	36599	1.95
T_7- Vermicompost (2.5 t ha^{-1}) + S (10 kg/ha)	39100	80346	41246	2.05
T_8- Vermicompost (2.5 t ha^{-1}) + S (20 kg/ha)	39700	84109	44409	2.12

4. CONCLUSION

The present study demonstrated that the integrated application of vermicompost (2.5 t ha^{-1}) with sulphur (20 kg ha^{-1}) (T_8) significantly improved plant growth, yield attributes, soil fertility, and economic returns compared to other treatments and the control. This combination led to the tallest plants, highest grain yield (885.36 kg ha^{-1}), improved soil nutrient status, and maximum net return (₹44,409/ha) with a B:C ratio of 2.12. Vermicompost not only enriched soil organic carbon and reduced bulk density but also enhanced the availability of nitrogen, phosphorus, potassium, and sulphur. These findings underscore the potential of vermicompost and sulphur as sustainable components of integrated nutrient management strategies for improving crop productivity and soil health in a cost-effective manner.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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