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Effect of organic nutrient management practices on NPK uptake and economics of sesame

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ABSTRACT

A field experiment was conducted during late kharif 2019 at College Farm, Agricultural College, Polasa, Jagtial, PJTAU, Telangana to evaluate the effect of organic nutrient management practices on nutrient uptake and economics of sesame (Sesamum indicum L.). The experiment was laid out in a Factorial RBD design with four main treatments of organic nutrient sources (FYM, vermicompost, enriched vermicompost, neem cake, humic acid, and microbial consortia) and four sub-treatments of foliar organics (Panchagavya, NSKE, vermiwash, humic acid) replicated thrice. Results revealed that nutrient uptake of sesame was significantly influenced by main treatments, foliar sprays, and their interactions. Among main treatments, application of 75% N through FYM + 25% N through enriched vermicompost + microbial consortia (T_4) recorded the highest uptake of N (9.35 and 15.86 kg ha^{-1}), P (5.58 and 9.16 kg ha^{-1}), and K (6.48 and 2.88 kg ha^{-1}) by stalk and seed, respectively, followed by T_2 (50% N through FYM + 25% N through enriched vermicompost + microbial consortia). Among foliar applications, Panchagavya @ 3% (S_1) enhanced nutrient uptake, particularly in the seed, and was at par with humic acid. Interaction of T_4 with S_1 (T_4S_1) consistently recorded superior nutrient uptake. Economic analysis indicated that T_4 realized the highest gross returns (₹73,023 ha^{-1}), net returns (₹41,642 ha^{-1}), and benefit–cost ratio (2.33), followed by T_2. Among foliar sprays, S_1 (Panchagavya @ 3%) recorded the highest net returns (₹37,108 ha^{-1}) and B:C ratio (2.14). The interaction T_4S_1 registered maximum profitability (B:C ratio 2.44). It may be concluded that the integrated application of FYM with enriched vermicompost and microbial consortia, coupled with foliar spray of Panchagavya, is effective in enhancing nutrient uptake and ensuring higher profitability of sesame under rainfed organic farming systems.

Keywords: *NPK Uptake, Economics, Cost of cultivation, Net returns, Gross returns, Benefit cost ratio.*

1. Introduction

Sesame (*Sesamum indicum L.*), popularly known as the "queen of oilseeds", is one of the oldest oilseed crops cultivated for its high-quality edible oil, which contains about 85% unsaturated fatty acids and natural antioxidants. It plays a vital role in human nutrition, health care, and cosmetic industries. Globally, sesame is grown on 12.5 million hectares with an annual production of 6.35 million tonnes, where India contributes the largest share in both area (29.8%) and production (25.8%), besides accounting for about 40% of global exports [9]. In India, sesame is cultivated on nearly 1.0 million hectares with a production of 0.82 million tonnes, while Telangana stands as one of the important producing states with higher productivity levels compared to the national average [9]. Owing to its short duration, low input requirement, and wider adaptability, sesame fits well in multiple cropping systems and is a potential export-oriented crop [8].

Modern agriculture in India has heavily relied on chemical fertilizers and pesticides since the Green Revolution. Fertilizer consumption has increased from 7.7 million tonnes in 1984–85 to more than 31 million tonnes in 2022–23, with urea alone accounting for nearly 60% of the total use [5]. Although this has contributed to higher yields initially, the indiscriminate and imbalanced application of fertilizers has led to soil degradation, nutrient mining, declining factor productivity, and environmental pollution[10],[3]. Moreover, pesticide residues and heavy reliance on chemical inputs have raised concerns in export markets, particularly for high-value crops like sesame [1].

Organic farming offers a sustainable alternative by promoting soil fertility, ecological balance, and biodiversity without the use of synthetic chemicals. India has brought 10.17 million hectares under organic certification (2023–24), producing about 3.60 million MT of diverse certified products, including cereals, pulses, fruits, spices, and oilseeds [1]. However, the biggest challenge in organic farming lies in nutrient management, since inorganic fertilizers are not permitted, necessitating the use of farmyard manure, compost, green manures, and biofertilizers for sustaining productivity[12].

Sesame, being a premium export crop, is highly sensitive to residue-related trade barriers. Organically grown sesame not only ensures residue-free, export-quality produce but also secures premium prices in global markets [8]. Hence, there is a strong need to optimize organic nutrient management practices in sesame under rainfed conditions to enhance yields, maintain soil health, and ensure environmental sustainability.

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2. Material and Methods

2.1 Experimental site and soil

The field experiment was conducted during late kharif 2019 at the College Farm, Agricultural College, Polasa, Jagtial, Professor Jayashankar Telangana Agricultural University, Telangana. The farm is situated at an altitude of 243.4 m above mean sea level, at 18º49′40″ N latitude and 78º56′45″ E longitude, and falls under the Northern Zone of Telangana (Fig. 1). The weekly mean maximum temperature during the crop growth period ranged between 29.2–32.3°C, with a mean of 31.2°C, while the minimum temperature ranged between 15.6–24.1°C, with a mean of 21.1°C. The total rainfall received during the crop period was 465.1 mm, distributed over 37 rainy days, with maximum rainfall (104.5 mm) received in the 39th standard week. The soil of the experimental site was sandy loam in texture, neutral in reaction, non-saline, low in available nitrogen, medium in phosphorus and potassium. Composite soil samples (0–30 cm) were collected before sowing and after harvest for initial and post-harvest soil analysis.

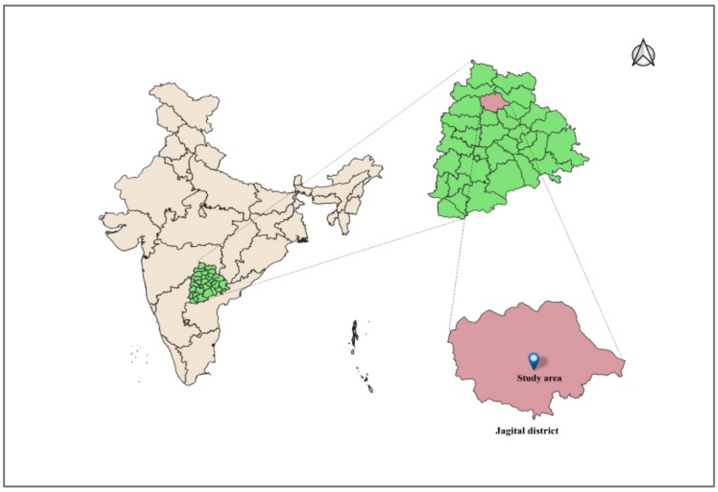

Fig 1. Location of the experiment

2.2 Experimental details and treatments

The experiment was laid out in a Factorial RBD design with four main treatments of organic nutrient management and four sub treatments of foliar organic sprays, replicated thrice. The main plot treatments consisted of T_1: 50% N through FYM + 25% N through vermicompost + 25% N through neem cake, T_2: 50% N through FYM + 25% N through vermicompost enriched with rock phosphate along with microbial consortia @ 2 kg ha^{-1}, T_3: 50% N through FYM + 25% N through neem cake + humic acid granules @ 12.5 kg ha^{-1}, and T_4: 75% N through FYM + 25% N through vermicompost enriched with rock phosphate along with microbial consortia @ 2 kg ha^{-1}. The sub treatments included S_1: foliar spray of *Panchagavya* @ 3%, S_2: NSKE @ 3%, S_3: vermiwash @ 10 ml L^{-1}, and S_4: humic acid @ 1 ml L^{-1}, imposed at flowering, 52 DAS, and 59 DAS. The recommended dose of fertilizers for sesame under rainfed conditions was 60:20:40 kg N:P_2O_5:K_2O ha^{-1}. Nutrient contribution from organic sources was computed, and the balance of P and K was supplied through straight fertilizers. Organic inputs (FYM, vermicompost, neem cake, enriched vermicompost) were chemically analyzed for nutrient content as per standard procedures [2].

2.3 Crop management

The sesame variety JCS-1020, released from RARS, Jagtial, was used. The crop was sown at 30 cm spacing between rows using a seed rate of 2.5 kg acre^{-1}. Gap filling was done at 10 DAS, thinning at 20 DAS, and weeds were controlled manually at 25 and 45 DAS. Three foliar sprays as per sub-treatments were imposed at flowering, 52 DAS, and 59 DAS. Biocontrol agents such as *Bacillus thuringiensis* and *Trichoderma viride* were applied for pest and disease management. The crop was grown under rainfed conditions, with two supplemental irrigations given at pod filling (60 and 75 DAS) due to lack of rainfall. Harvest was completed on 5 December 2019.

2.4 Nutrient uptake studies

Plant samples were collected at harvest from each plot, oven-dried at 65°C, ground, and analysed for N, P, and K uptake. Total nutrient uptake was calculated by multiplying nutrient concentration in grain and stover with their respective yields and expressed as kg ha^{-1}.

2.5 Economics

The cost of cultivation for each treatment was calculated based on prevailing local prices of inputs and operations. Gross returns were worked out from grain yield multiplied by the minimum support price (MSP) of sesame prevailing in 2019. Net returns were obtained by deducting the cost of cultivation from gross returns. Benefit–cost ratio (B:C) was computed as the ratio of gross returns to cost of cultivation.

3. Results and Discussion

3.1 Seed and stalk yield of sesame

The seed and stalk yields of sesame were significantly influenced by the main organic nutrient management practices and their interaction with foliar sprays, whereas the effect of foliar treatments alone was non-significant (Fig.2). Among the main treatments, T_4 (75% N through FYM + 25% N through enriched vermicompost + microbial consortia @ 2 kg ha^{-1}) recorded the highest seed yield (478 kg ha^{-1}) and stalk yield (827 kg ha^{-1}), followed by T_2 (433 and 772 kg ha^{-1}, respectively). These were statistically at par with T_1 (424 and 748 kg ha^{-1}, respectively), while the lowest yields were obtained in T_3 (405 and 712 kg ha^{-1}, respectively). The higher productivity with T_4 and T_2 could be attributed to the balanced and prolonged nutrient supply from diversified organic sources, including the beneficial role of microbial consortia in nitrogen fixation and phosphorus solubilization [4],[7].

Though foliar sprays did not show significant differences, numerically higher seed and stalk yields were recorded with *Panchagavya* @ 3%, followed by humic acid, NSKE, and vermiwash. Their positive influence may be due to enzymatic and hormonal effects that enhanced nutrient uptake, crop quality, and resistance to pests and diseases [17], [6].

The interaction effects were significant, with the combination T_4S_3 (basal T_4 + foliar vermiwash) producing the highest seed yield (508 kg ha^{-1}), while T_4S_1 (basal T_4 + foliar *Panchagavya*) produced the highest stalk yield (858 kg ha^{-1}). These were statistically comparable with other T_4-based combinations (T_4S_2, T_4S_3, T_4S_4) and with T_2S_1 and T_1S_1. Significantly lower seed and stalk yields were observed in T_2S_3 (381 kg ha^{-1}) and T_3S_1 (708 kg ha^{-1}), respectively.

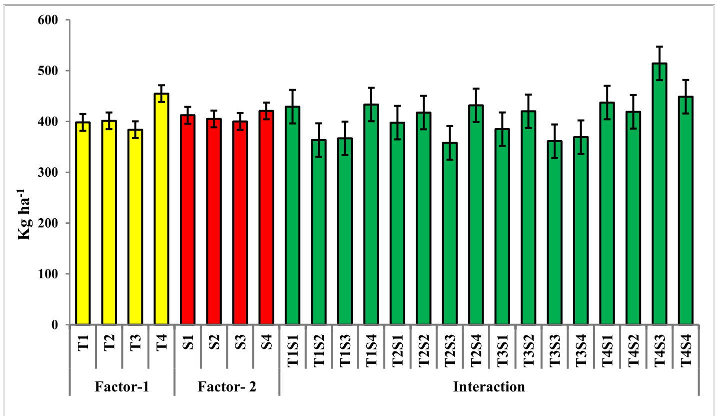

Fig 2. Seed yield of sesame under the influence of organic nutrient management practices

3.2 Nutrient uptake

3.2.1Nitrogen uptake

Nitrogen uptake in sesame stalk and seed at harvest was significantly influenced by the main treatments, while seed N uptake was also affected by foliar organic nutrient applications (Table1). Among the main treatments, T_4 (75% N through FYM + 25% N through vermicompost enriched with rock phosphate + microbial consortia @ 2 kg ha^{-1}) recorded the highest N uptake in stalk (9.35 kg ha^{-1}) and seed (15.86 kg ha^{-1}), which was statistically on par with T_2 (50% N through FYM + 25% N through enriched vermicompost + microbial consortia) (8.33 and 13.35 kg ha^{-1}, respectively). These treatments were followed by T_1 (50% N through FYM + 25% N through vermicompost + 25% N through neem cake), while the lowest uptake was observed with T_3 (50% N through FYM + 25% N through neem cake + humic acid granules @ 12.5 kg ha^{-1}). The enhanced N uptake under T_4 and T_2 could be attributed to higher biological yield and steady nutrient release from diversified organic sources ensuring prolonged nutrient availability [14], [16].

With respect to foliar sprays, N uptake in stalk was not significantly influenced, whereas N uptake in seed differed significantly. The highest seed N uptake (14.09 kg ha^{-1}) was recorded with *Panchagavya* @ 3%, which was comparable with humic acid @ 1 ml L^{-1} (13.45 kg ha^{-1}) and vermiwash @ 10 ml L^{-1} (12.95 kg ha^{-1}). The lowest N uptake (12.78 kg ha^{-1}) was observed with NSKE @ 3%. The superiority of *Panchagavya* and humic acid in improving nutrient absorption and assimilation has also been reported earlier [17], [6].

The interaction between basal and foliar organic nutrient treatments was also significant (Fig 3). The highest N uptake in stalk (9.95 kg ha^{-1}) and seed (16.40 kg ha^{-1}) was recorded with T_4S_1 (basal T_4 + foliar *Panchagavya* @ 3%), which was on par with T_4S_4, T_4S_3, T_2S_1, and T_2S_4 for seed N uptake, and with $T_4S_3$for stalk N uptake.

3.2.2Phosphorus uptake

Phosphorus uptake by sesame was significantly affected by main treatments, sub-treatments (only stalk), and their interaction (Table 1). Among main treatments, T_4 recorded the highest P uptake in seed (9.16 kg ha^{-1}), followed by T_2 (7.90 kg ha^{-1}), which was statistically comparable with T_1 in seed (7.40 kg ha^{-1}). The lowest uptake was obtained in T_3 (6.74 kg ha^{-1} in seed). However, there was no significant difference in stalk p uptake was observed by treatment effect. The higher uptake in T_4 and T_2 may be attributed to enriched vermicompost and microbial consortia, which enhanced nutrient mineralization, root proliferation, and better P availability [15].

Foliar treatments also not significantly influenced P uptake in seed as well as stalk.

Table 1. NPK uptake at harvest (kg ha-1) by sesame as influenced by Organic nutrient management practices

Treatments	N uptake		P uptake		K uptake	
	Stalk	Seed	Stalk	Seed	Stalk	Seed
Main Treatments						
T_1: 50 % N through FYM + 25 % N through vermicompost + 25 % N through Neem cake	7.97	12.59	5.48	7.40	5.55	2.47
T_2: 50 % N through FYM + 25 % N through vermicompost enriched with rock phosphate + microbial consortia @ 2 kg ha^{-1}	8.33	13.35	5.56	7.90	6.04	2.61
T_3: 50 % N through FYM + 25 % N through Neem cake + Humic acid granules @ 12.5 kg ha^{-1}	7.39	11.63	5.06	6.74	5.19	2.32
T_4: 75 % N through FYM + 25 % N through vermicompost enriched with rock phosphate + microbial consortia @ 2 kg ha^{-1}	9.35	15.86	5.58	9.16	6.48	2.88
SEm±	0.34	0.46	0.26	0.24	0.12	0.11
CD (P=0.05)	0.82	1.24	NS	0.65	0.40	0.26
Sub treatments						
S_1: *Panchagavya* @ 3 %	8.59	14.09	5.28	8.02	6.17	2.76
S_2: NSKE@ 3 %	8.04	12.78	5.26	7.77	5.67	2.38
S_3: Vermiwash @ 10ml lit^{-1}	8.04	12.95	5.22	7.57	5.60	2.50
S_4: Humic acid @ 1ml lit^{-1}	8.32	13.45	5.06	7.82	5.84	2.63
SEm±	0.34	0.46	0.26	0.24	0.12	0.11
CD (P=0.05)	NS	1.24	NS	NS	0.40	0.26
Interaction (T X S)						
SEm±	0.66	0.84	0.51	0.44	0.24	0.22
CD (P=0.05)	1.64	2.46	NS	1.30	0.80	0.53

The interaction effect was significant, with T_4S_1 (9.51 kg ha^{-1}in seed) being superior, and statistically comparable with T_4S_4, T_4S_2, T_4S_3, and T_2S_1 (Fig 3).

3.2.3 Potassium uptake

Potassium uptake was significantly influenced by main treatments, foliar treatments, and their interactions (Table 1). The highest K uptake in stalk (6.48 kg ha^{-1}) and seed (2.88 kg ha^{-1}) was recorded with T_4, followed by T_2 (6.04 and 2.61 kg ha^{-1}, respectively), which was on par with T_1 in seed (2.47 kg ha^{-1}). The lowest uptake was observed with T_3 (5.19 and 2.32 kg ha^{-1}, respectively). The improved K uptake with vermicompost may be due to enhanced microbial activity and conversion of unavailable K into exchangeable forms [15].

Among foliar sprays, *Panchagavya* @ 3% recorded the highest K uptake (6.17 and 2.76 kg ha^{-1} in stalk and seed, respectively), which was on par with humic acid @ 1 ml L^{-1} (5.84 and 2.63 kg ha^{-1}). The lowest values were observed with vermiwash @ 10 ml L^{-1} (5.60 kg ha^{-1}) in stalk and with NSKE @ 3% (2.38kg ha^{-1}) in seed.

Interaction effects were also significant. The maximum K uptake was observed with T_4S_1 (6.92 and 3.09 kg ha^{-1} in stalk and seed, respectively), which was comparable with T_4S_4, T_4S_2, T_4S_3, T_2S_4, T_1S_1, and T_1S_4 (Fig. 3). The lowest uptake values were obtained in T_3S_2 (4.93 kg ha^{-1} stalk) and T_1S_2 (2.14 kg ha^{-1} seed).

3.3 Economics

Organic farming systems are often reported to produce slightly lower yields than conventional systems. However, the overall profitability is generally higher due to premium prices for certified produce and lower dependence on synthetic inputs. Studies have shown that even with a reduction of about 9–10% in productivity, organic farming can provide 20–25% higher net profits when premium price realizations (20–40%) and reduced input costs (around 10–12%) are considered [11]. Against this background, the present study evaluated the effect of organic nutrient management practices on cost of cultivation, gross returns, net returns, and benefit–cost ratio of sesame.

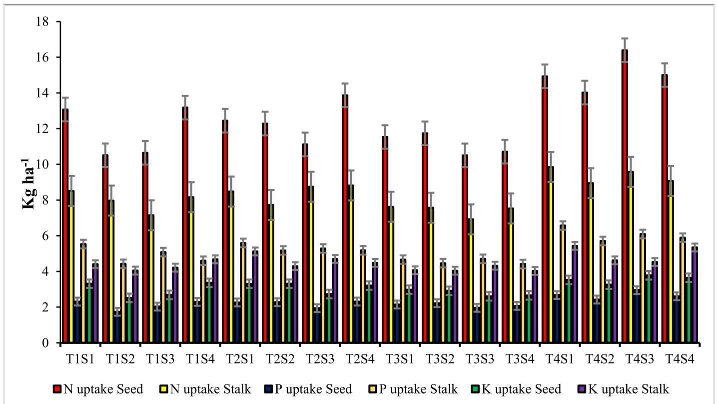

Fig 3. Interaction effect of organic nutrient management practices in sesamum

3.3.1 Cost of cultivation

The influence of organic nutrient management practices on the cost of cultivation of sesame is presented in Fig 4. Among the main treatments, the highest cost of cultivation was incurred in T_1 (50% N through FYM + 25% N through vermicompost + 25% N through neem cake) (₹34,356 ha^{-1}), followed by T_3 (50% N through FYM + 25% N through neem cake + humic acid granules @ 12.5 kg ha^{-1}) (₹32,306 ha^{-1}) and T_4 (75% N through FYM + 25% N through enriched vermicompost + microbial consortia). The lowest cultivation cost was recorded in T_2 (50% N through FYM + 25% N through enriched vermicompost + microbial consortia). The higher cost in T_1 and T_3 was mainly due to the higher price of neem cake.

Across foliar sprays, the cost of cultivation varied only marginally, ranging from ₹31,744 with vermiwash to ₹32,419 with *Panchagavya*. The variation was due to differences in input costs, with *Panchagavya*, NSKE, vermiwash, and humic acid costing ₹750, ₹450, ₹75, and ₹350 per hectare, respectively. Similar observations were made [11], who reported that in organic systems, FYM accounted for the major share of cost (29.3%) followed by labour (27.8%) due to the requirement of manual weeding and other field operations.

3.3.2 Gross returns

Gross returns were calculated using the market price of sesame seed at ₹150 kg^{-1} and stalk at ₹5 kg^{-1}. The highest gross returns were obtained with T_4 (₹73,023 ha^{-1}), followed by T_2 (₹66,082 ha^{-1}), which was statistically at par with T_1 (₹64,711 ha^{-1}). The lowest gross returns were observed in T_3 (Table 2). The superior performance of T_4 was due to higher seed and stalk yields, coupled with efficient nutrient supply through enriched vermicompost and microbial consortia. The findings are in line with [11], who highlighted the ecological and economic advantages of organic nutrient sources.

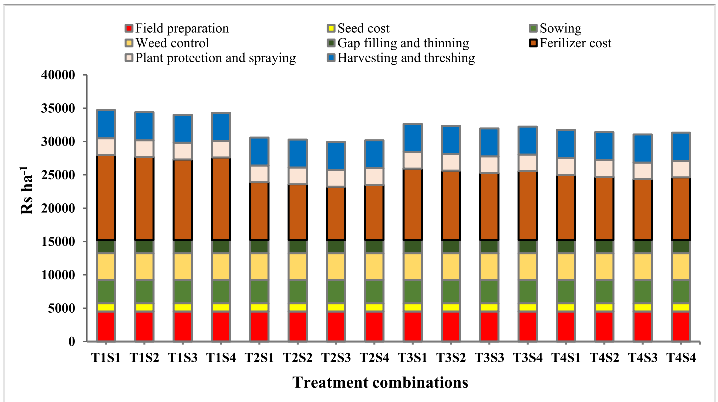

Fig 4. Cost of cultivation of sesamum under different organic nutrient management practices

Among foliar treatments, although differences were statistically non-significant, the highest gross returns were recorded in S_1 (*Panchagavya* @ 3%) (₹69,527 ha^{-1}). Other treatments, viz., NSKE, vermiwash, and humic acid, yielded ₹65,610, ₹64,731, and ₹65,825 ha^{-1}, respectively, which were comparable. A higher gross return from *Panchagavya* was also documented by [17].

The interaction between main and sub treatments was significant. The maximum gross returns were recorded with T_4S_1 (₹77,472 ha^{-1}), which was at par with T_4S_2, T_2S_1, T_4S_3, T_4S_4, T_1S_1, and T_2S_2. These results corroborate earlier findings by [11].

Net returns

Net returns, derived by subtracting cost of cultivation from gross returns, were significantly affected by organic nutrient management (Table 2). The maximum net returns were.

Table 2. Gross returns, Net returns and Benefit Cost ratio of Sesame as influenced by Organic nutrient management practices

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefit Cost ratio
Main Treatments			
T_1: 50 % N through FYM + 25 % N through vermicompost + 25 % N through Neem cake	64710	30354	1.88
T_2: 50 % N through FYM + 25 % N through vermicompost enriched with rock phosphate + microbial consortia@2 kg ha^{-1}	66082	35826	2.18
T_3: 50 % N through FYM + 25 % N through Neem cake + Humic acid granules @ 12.5 kg ha^{-1}	61878	29572	1.92
T_4: 75 % N through FYM + 25 % N through vermicompost enriched with rock phosphate + microbial consortia@2 kg ha^{-1}	73023	41642	2.33
SEm±	1827.0	1827.0	0.07
CD (P=0.05)	5275.9	5275.9	0.25
Sub treatments			
S_1: *Panchagavya* @ 3 %	69527	37108	2.14
S_2: NSKE@ 3 %	65610	33491	2.04
S_3: Vermiwash @ 10ml lit^{-1}	64731	32988	2.04
S_4: Humic acid @ 1ml lit^{-1}	65825	33807	2.06
SEm±	1827.0	1827.0	0.07
CD (P=0.05)	NS	NS	NS
Interaction (T X S)			
SEm±	3653.9	3653.9	0.15
CD (P=0.05)	10551.9	10551.9	0.42

recorded in T_4 (₹41,642 ha^{-1}), followed by T_2 (₹35,826 ha^{-1}), while the lowest were observed in T_3 (₹29,572 ha^{-1}).
Among foliar sprays, S_1 (*Panchagavya* @ 3%) registered the highest net returns (₹37,108 ha^{-1}), while S_3 (Vermiwash@ 10ml lit^{-1}) recorded the lowest (₹32,988 ha^{-1}). Net returns under NSKE and humic acid sprays were statistically at par with *Panchagavya*.

3.3.3 Benefit–cost ratio

The benefit–cost ratio was also significantly influenced by organic nutrient management practices. The highest B:C ratio was observed in T_4 (2.33), followed by T_2 (2.18). The use of enriched vermicompost and microbial consortia along with FYM contributed to higher yields with relatively lower input costs, supporting earlier findings by [15] and [11]. The lowest B:C ratio was recorded in T_3 (1.92).
Among foliar sprays, differences were not statistically significant, though the highest B:C ratio was recorded in S_1 (2.14), followed by S_4 (2.06).The lowest B:C ratio was observed in both S_2 and S_3(2.04).
The interaction between main and sub treatments was significant. The highest B:C ratio was recorded with T_4S_1 (2.44), which was at par with T_4S_2, T_4S_3, T_2S_2, T_4S_4, and T_2S_1. These results highlight that organic farming not only improves ecological sustainability but also ensures profitability, provided premium price markets are accessible. However, the time required for conversion of conventional land to organic, along with farmers' awareness and policy support, remains critical for large-scale adoption[11].

4. Conclusion

The present study demonstrated that organic nutrient management practices significantly influenced nutrient uptake and profitability of sesame under rainfed conditions. Among the treatments, the application of 75% N through FYM + 25% N through enriched vermicompost along with microbial consortia (T_4) consistently recorded the highest uptake of N, P, and K by both stalk and seed, resulting in superior yield and economic returns. Foliar application of *Panchagavya* @ 3% (S_1) further improved nutrient uptake, net returns, and benefit–cost ratio, with the combination T_4S_1 proving most effective. The findings highlight that integrating FYM with enriched vermicompost and microbial consortia, coupled with foliar organics like *Panchagavya*, not only enhances nutrient absorption and yield but also improves profitability of sesame cultivation in organic farming systems. These results suggest that adoption of such practices can contribute to sustainable sesame production, ecological security, and higher income for farmers in rainfed regions.

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