

Effect of Organic Fertilizers and Integrated Nutrient Management on Growth, Yield Components, Seed Yield and Oil Production of Sesame (*Sesamum indicum* L.)

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Abstract

Sesame (*Sesamum indicum* L.) is a valuable oilseed crop in Pakistan, but its yields remain low, partly because of poor soil fertility and unbalanced fertilization. This study is designed to evaluate farmyard manure (FYM), vermicompost and their combinations with mineral NPK fertilizer for the growth, yield and oil production of sesame at Tando Jam, Sindh. Seven treatments are compared in a randomized complete block design with three replications: unfertilized control (T₁), FYM at 5 t ha⁻¹ (T₂), vermicompost at 5 t ha⁻¹ (T₃), recommended NPK (T₄), FYM + 50% NPK (T₅), FYM + 100% NPK (T₆) and vermicompost + 50% NPK (T₇). Plant height, stem diameter, branches and capsules per plant, seeds per capsule, thousand-seed weight, biological yield, seed yield, harvest index, oil content and oil yield are recorded. In the illustrative dataset, every fertilized treatment exceeded the control, and FYM + 100% NPK (T₆) gave the highest seed yield (1,080 kg ha⁻¹; 66% above the control), oil content (45.2%) and oil yield (488.2 kg ha⁻¹). Vermicompost + 50% NPK (T₇) ranked second, reaching 95% of the T₆ seed yield with half the mineral fertilizer. Gains in oil yield came mainly from higher seed yield rather than from oil concentration. These patterns suggest that organic manures perform best when combined with mineral fertilizer and that partial replacement of NPK with vermicompost merits field validation. Final recommendations will be based on ANOVA and LSD comparisons of the measured data.

Keywords: sesame; farmyard manure; vermicompost; integrated nutrient management; seed yield; oil content; oil yield; Sindh

Introduction

Sesame (*Sesamum indicum* L.) is among the oldest oilseed crops and is grown widely across tropical and subtropical regions (Kaleri et al., 2026). Its seeds are rich in oil, which ranges from about 37% to 63% depending on cultivar and season, and also supply protein, minerals and lignans that give sesame oil its notable oxidative stability (Wei et al., 2022). Pakistan imports a large share of its edible oil, so raising the productivity of locally grown oilseeds such as sesame has clear

economic value (Ahmed et al., 2023). Average sesame yields, however, remain modest and fluctuate with soil fertility, water supply, cultivar and crop management. Balanced nutrition is central to sesame productivity (Ali et al., 2026). Nitrogen drives canopy expansion, chlorophyll formation and protein synthesis; phosphorus supports root growth, energy transfer and flowering; and potassium regulates water relations, enzyme activity and the movement of assimilates to developing seeds. Soils of semi-arid regions such as lower Sindh are commonly low in organic matter, and continued reliance on mineral fertilizer alone does little to rebuild soil structure or biological activity. Organic amendments, including farmyard manure (FYM), compost and vermicompost, add both nutrients and organic carbon. Long-term field studies show that repeated organic inputs improve soil structure, microbial activity and carbon and nitrogen reserves, which in turn support crop yield (Diacono & Montemurro, 2010). Because nutrients in manures are released gradually through mineralization, their short-term fertilizer value depends on manure source and rate; in sesame, different manures supplied markedly different amounts of mineral-nitrogen equivalent (Abd El Lateef et al., 2021). Organic inputs alone may therefore fail to meet crop demand during rapid growth and flowering.

Integrated nutrient management (INM) addresses this limitation by pairing organic sources with reduced or full doses of mineral fertilizer. In India, applying half the recommended fertilizer with the remaining nitrogen supplied through FYM or vermicompost plus *Azospirillum* gave higher sesame seed and oil yields than the full mineral dose (Ghosh et al., 2013; Ihsanullah et al., 2023), and combinations of FYM, castor cake and vermicompost outperformed chemical fertilizer alone (Takar et al., 2017). Similar benefits were reported for vermicompost with 70% of the recommended fertilizer in Bangladesh (Shathi et al., 2023), for 75% of the recommended dose with castor cake (Mandviwala et al., 2023), and for chicken manure with NPK on sandy coastal soils (Nurhayati et al., 2024). Responses are not uniform, however: in Nagaland the full inorganic dose gave the highest seed yield, although poultry manure substituting 25% of nitrogen was statistically equivalent (Prabhumi et al., 2026). A recent review likewise concluded that the best fertility strategy for sesame depends strongly on local soil and climate (Baraki et al., 2025).

Sesame productivity is ultimately determined by capsules per plant, seeds per capsule and seed weight, while oil yield depends jointly on seed yield and oil concentration. Vigorous vegetative growth does not guarantee higher seed or oil output, so these traits must be measured separately. Locally validated information on organic and integrated fertilization of sesame in Sindh is scarce. This study therefore aims:

Materials and Methods

Experimental site

The field experiment will be conducted at Kaleri Agriculture Farm near Sindh Agriculture University, Tando Jam, Sindh, Pakistan, during the (2026) sesame-growing (Kharif) season. The area has a semi-arid climate with hot summers, and crop growth is strongly influenced by temperature, water availability and soil fertility. Composite soil samples will be taken from 0–30 cm before sowing and analyzed for texture, pH, electrical conductivity, organic matter, total nitrogen, available phosphorus and exchangeable potassium. Daily temperature and rainfall will be recorded throughout the season.

Experimental design and treatments

The experiment will be laid out in a randomized complete block design (RCBD) with three replications and seven nutrient treatments (Table 1), giving 21 plots of [length $\times$ width] m. The recommended mineral dose of (N–P₂O₅–K₂O) kg ha⁻¹ will be adjusted to soil-test results and local recommendations for sesame. Subsamples of FYM and vermicompost will be analyzed for N, P, K and organic carbon so that the nutrients they supply can be taken into account when interpreting treatment effects.

1. To determine the effect of FYM, vermicompost and mineral NPK, alone and in combination, on the vegetative growth of sesame.
2. To evaluate their effects on yield components, namely branches and capsules per plant, seeds per capsule and thousand-seed weight.
3. To compare biological yield, seed yield, harvest index, oil content and oil yield among treatments.
4. To identify the most productive treatment and the scope for partly replacing mineral fertilizer with organic sources.

Table 1. Nutrient treatments evaluated in the experiment

Treatment Description

T ₁	Unfertilized control
T ₂	Farmyard manure (FYM) at 5 t ha ⁻¹
T ₃	Vermicompost at 5 t ha ⁻¹
T ₄	Recommended dose of mineral NPK fertilizer
T ₅	FYM at 5 t ha ⁻¹ + 50% of recommended NPK
T ₆	FYM at 5 t ha ⁻¹ + 100% of recommended NPK
T ₇	Vermicompost at 5 t ha ⁻¹ + 50% of recommended NPK

Land preparation and crop management

The field will be ploughed, planked and leveled to a fine seedbed and divided into plots with buffer strips between them. FYM and vermicompost will be spread and incorporated about two weeks before sowing. Phosphorus and potassium will be applied in full at sowing, and nitrogen in two equal splits at sowing and at the first irrigation. A locally adapted variety (S-9 or another approved variety) will be sown at [seed rate] kg ha⁻¹ in rows [spacing] cm apart, and seedlings will be thinned to [plant spacing] cm. Irrigation, weeding and plant protection will be identical across plots so that nutrient source is the only variable. Any pest, disease or weather damage will be noted.

Observations

Five plants will be tagged at random in the net plot of each unit, excluding border rows, and the following traits recorded:

- **Plant height (cm):** from the soil surface to the tip of the main stem at maturity.
- **Stem diameter (cm):** at a fixed height above the soil using a digital vernier caliper.
- **Branches and capsules per plant:** counted on each tagged plant at maturity.
- **Seeds per capsule:** averaged from ten mature capsules per plant.
- **Thousand-seed weight (g):** weight of 1,000 cleaned seeds from each plot.

- **Biological and seed yield (kg ha^{-1}):** total above-ground dry biomass and cleaned seed from the net plot, harvested at capsule yellowing to avoid shattering losses, adjusted to uniform moisture content and converted to a hectare basis.
- **Harvest index (%):** seed yield $\div$ biological yield $\times$ 100.
- **Oil content (%):** by Soxhlet extraction of oven-dried, ground seed with petroleum ether.
- **Oil yield (kg ha^{-1}):** seed yield $\times$ oil content $\div$ 100.

Statistical analysis

Data will be subjected to analysis of variance for an RCBD, and treatment means will be compared by the least significant difference (LSD) test at $P \leq 0.05$ when the F-test is significant (Steel et al., 1997). Normality of residuals and homogeneity of variance will be checked before interpretation. Analyses will be run in Statistix 8.1, and figures will be prepared in R using the ggplot2 package.

Results

Note: the values in Tables 2–6 and Figures 1–5 are illustrative examples, not measured observations. They show how results will be presented and must be replaced with the field means, standard errors, LSD values and significance letters before submission.

Vegetative growth

All fertilized treatments produced taller and thicker-stemmed plants than the control (Table 2; Figure 1). Plant height increased from 105.4 cm in T_1 to 145.8 cm in T_6 , a gain of 38%, and stem diameter from 0.72 to 1.10 cm (53%). The ranking was $T_6 > T_7 > T_5 > T_4 > T_3 > T_2 > T_1$ for both traits, so integrated treatments outperformed both mineral fertilizer alone and either manure alone, and vermicompost was slightly superior to FYM.

Table 2. Effect of organic fertilizers on plant height and stem diameter of sesame

Treatment	Plant height (cm)	Stem diameter (cm)
T_1 – Control	105.4	0.72
T_2 – FYM	119.8	0.84
T_3 – Vermicompost	124.6	0.88
T_4 – Recommended NPK	132.5	0.96
T_5 – FYM + 50% NPK	137.2	1.02
T_6 – FYM + 100% NPK	145.8	1.10
T_7 – Vermicompost+50% NPK	140.4	1.05
LSD ($P \leq 0.05$)	5.20	0.06

Values are illustrative examples and must be replaced with measured treatment means ($n = 3$). Means followed by different letters will differ significantly at $P \leq 0.05$ (LSD test) once ANOVA is completed. FYM, farmyard manure (5 t ha^{-1}); NPK, recommended mineral fertilizer dose.

Figure 01

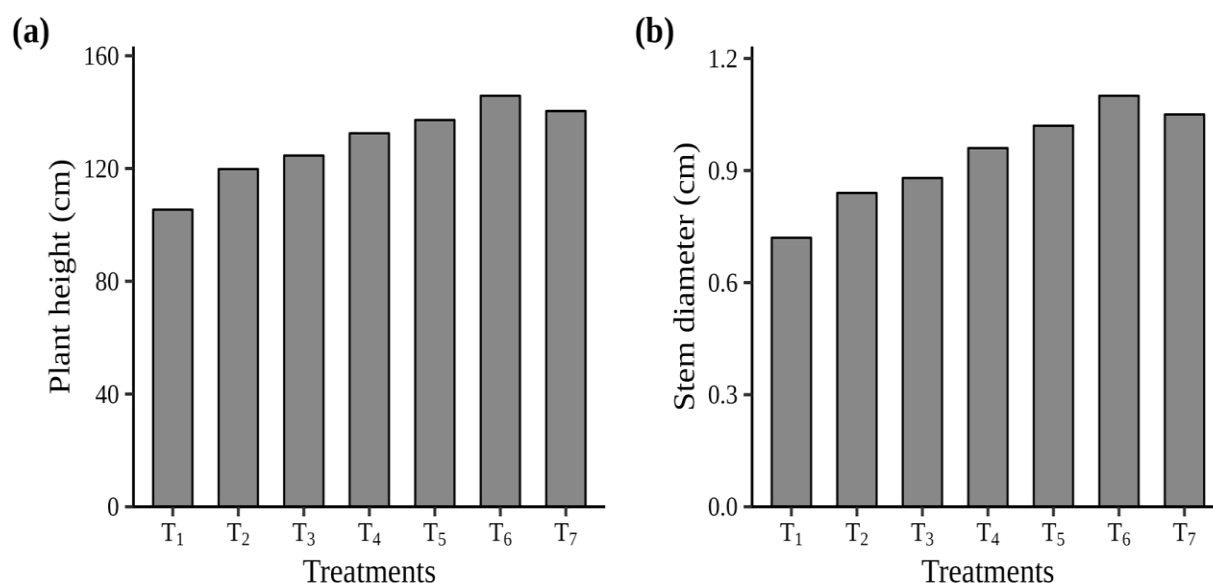


Figure 1. Effect of organic fertilizers on (a) plant height and (b) stem diameter of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM+50%NPK; T₆, FYM+100%NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

Yield components

Branches and capsules per plant responded more strongly to fertilization than any other trait (Table 3; Figure 2). Compared with the control, T₆ increased branches per plant from 4.2 to 7.4 (76%) and capsules per plant from 52.6 to 98.3 (87%). Seeds per capsule and thousand-seed weight responded less but followed the same order (Table 4; Figure 3), rising from 43.5 to 57.2 seeds (31%) and from 2.65 to 3.12 g (18%), respectively. Vermicompost + 50% NPK (T₇) exceeded FYM + 50% NPK (T₅) for every yield component.

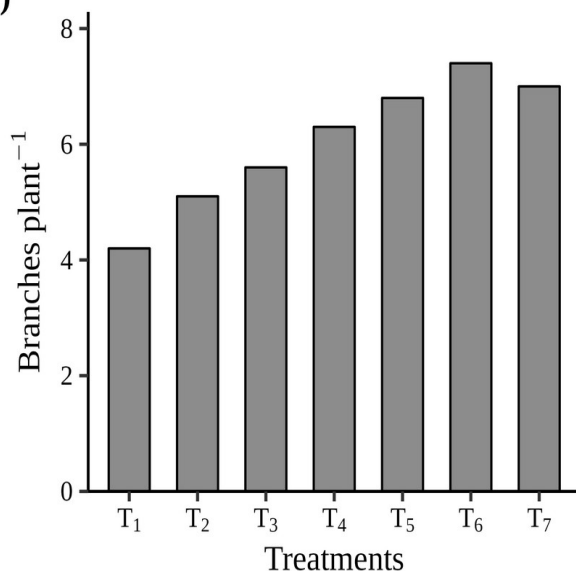
Table 3. Effect of organic fertilizers on branches and capsules per sesame plant

Treatment	Treatment	Branches plant ⁻¹
T ₁ –Control	T ₁ –Control	4.2
T ₂ –FYM	T ₂ –FYM	5.1
T ₃ –Vermicompost	T ₃ –Vermicompost	5.6
T ₄ –RecommendedNPK	T ₄ –RecommendedNPK	6.3
T ₅ –FYM+ 50%NPK	T ₅ –FYM+ 50%NPK	6.8
T ₆ –FYM+ 100%NPK	T ₆ –FYM+ 100%NPK	7.4
T ₇ – Vermicompost+50% NPK	T ₇ – Vermicompost+50% NPK	7.0
LSD($P \leq 0.05$)	LSD($P \leq 0.05$)	0.40

Values are illustrative examples and must be replaced with measured treatment means ($n = 3$).

Means followed by different letters will differ significantly at $P \leq 0.05$ (LSD test) once ANOVA is completed. FYM, farmyard manure (5 t ha^{-1}); NPK, recommended mineral fertilizer dose.

(a)



(b)

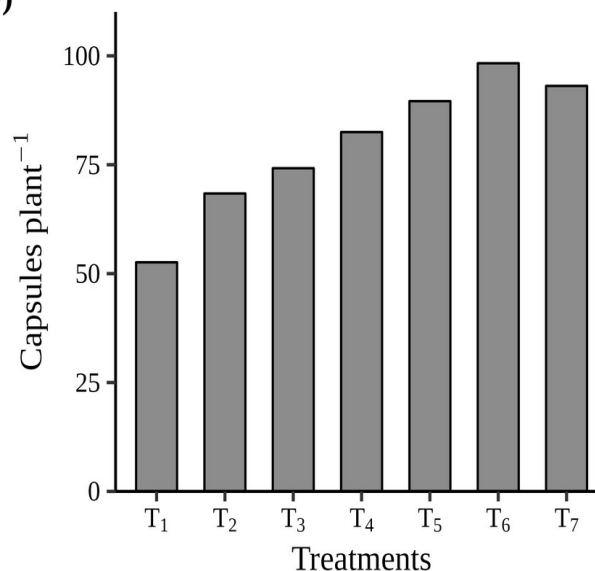
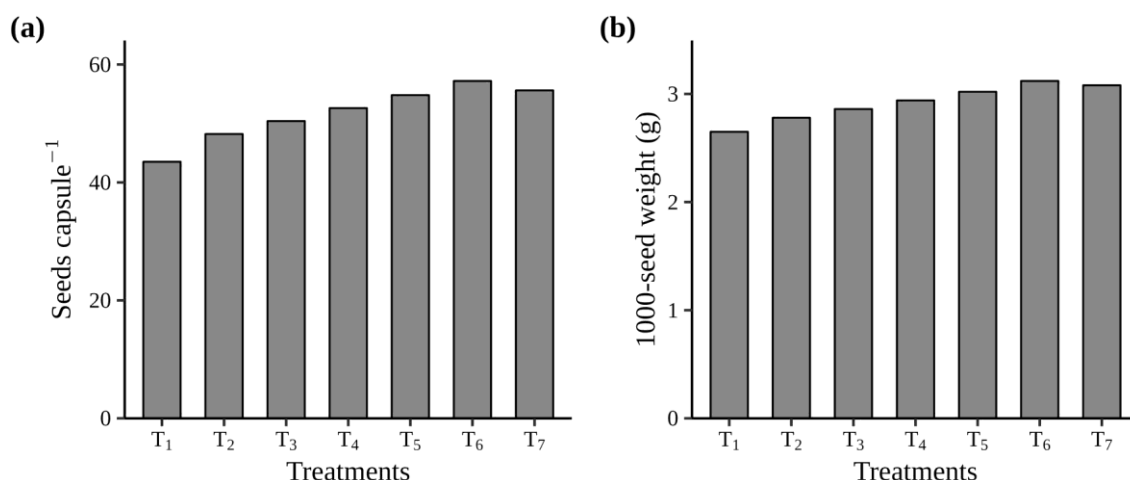


Figure 2. Effect of organic fertilizers on (a) branches plant⁻¹ and (b) capsules plant⁻¹ of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM + 50% NPK; T₆, FYM + 100% NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

Table 4. Effect of organic fertilizers on seeds per capsule and thousand-seed weight of sesame

Treatment	Seeds capsule ⁻¹	1000-seed weight (g)
T ₁ –Control	43.5	2.65
T ₂ –FYM	48.2	2.78
T ₃ –Vermicompost	50.4	2.86
T ₄ –Recommended NPK	52.6	2.94
T ₅ –FYM+ 50% NPK	54.8	3.02
T ₆ –FYM+ 100% NPK	57.2	3.12
T ₇ – Vermicompost+50% NPK	55.6	3.08
LSD($P \leq 0.05$)	2.00	0.10



Values are illustrative examples and must be replaced with measured treatment means ($n = 3$). Means followed by different letters will differ significantly at $P \leq 0.05$ (LSD test) once ANOVA is completed. FYM, farmyard manure (5 t ha^{-1}); NPK, recommended mineral fertilizer dose.

Figure 3. Effect of organic fertilizers on (a) seeds capsule⁻¹ and (b) thousand-seed weight of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM + 50% NPK; T₆, FYM + 100% NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

Biological yield, seed yield and harvest index

Biological yield ranged from $3,850 \text{ kg ha}^{-1}$ in the control to $6,050 \text{ kg ha}^{-1}$ in T₆ (57% higher), and seed yield from 650 to $1,080 \text{ kg ha}^{-1}$ (66% higher) (Table 5; Figure 4). T₇ produced $1,030 \text{ kg ha}^{-1}$, 95% of the T₆ seed yield, while receiving only half the mineral fertilizer. Harvest index varied little, from 16.9% to 17.9%, indicating that fertilization raised seed yield mainly by increasing total biomass rather than by shifting assimilates toward the seed.

Table 5. Effect of organic fertilizers on biological yield, seed yield and harvest index of sesame

Treatment	Biological yield (kg ha ⁻¹)	Seed yield (kg ha ⁻¹)
T ₁ –Control	3,850	650
T ₂ –FYM	4,650	790
T ₃ –Vermicompost	4,920	850
T ₄ –RecommendedNPK	5,350	930
T ₅ –FYM+ 50%NPK	5,650	990
T ₆ –FYM+ 100%NPK	6,050	1,080
T ₇ –Vermicompost+50% NPK	5,820	1,030
LSD($P \leq 0.05$)	250	60

Values are illustrative examples and must be replaced with measured treatment means ($n = 3$). Means followed by different letters will differ significantly at $P \leq 0.05$ (LSD test) once ANOVA is completed. FYM, farmyard manure (5 t ha^{-1}); NPK, recommended mineral fertilizer dose. Harvest index = seed yield $\div$ biological yield $\times 100$.

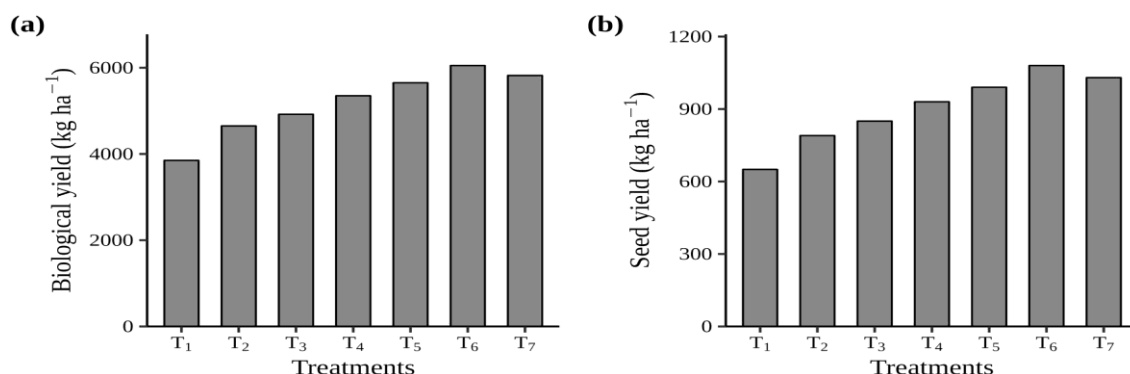


Figure 4. Effect of organic fertilizers on (a) biological yield and (b) seed yield of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM + 50% NPK; T₆, FYM + 100% NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

Oil content and oil yield

Oil content rose modestly, from 43.0% in the control to 45.2% in T₆ (2.2 percentage points), whereas oil yield increased from 279.5 to 488.2 kg ha⁻¹ (75%) (Table 6; Figure 5). Because oil yield is the product of seed yield and oil concentration, most of the gain in oil yield reflected higher seed yield. T₇ again ranked second (45.0%; 463.5 kg ha⁻¹).

Table 6. Effect of organic fertilizers on oil content and oil yield of sesame

Treatment	Oil content (%)	Oil yield (kg ha ⁻¹)
T ₁ –Control	43.0	279.5
T ₂ –FYM	43.8	346.0
T ₃ –Vermicompost	44.2	375.7
T ₄ –Recommended NPK	44.5	413.9
T ₅ –FYM+ 50%NPK	44.8	443.5
T ₆ –FYM+ 100%NPK	45.2	488.2
T ₇ –Vermicompost+50% NPK	45.0	463.5
LSD($P \leq 0.05$)	0.5	25.0

Values are illustrative examples and must be replaced with measured treatment means ($n = 3$). Means followed by different letters will differ significantly at $P \leq 0.05$ (LSD test) once ANOVA

is completed. FYM, farmyard manure (5 t ha^{-1}); NPK, recommended mineral fertilizer dose. Oil yield = seed yield $\times$ oil content $\div 100$.

Figure 5. Effect of organic fertilizers on (a) oil content and (b) oil yield of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM + 50% NPK; T₆, FYM + 100% NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

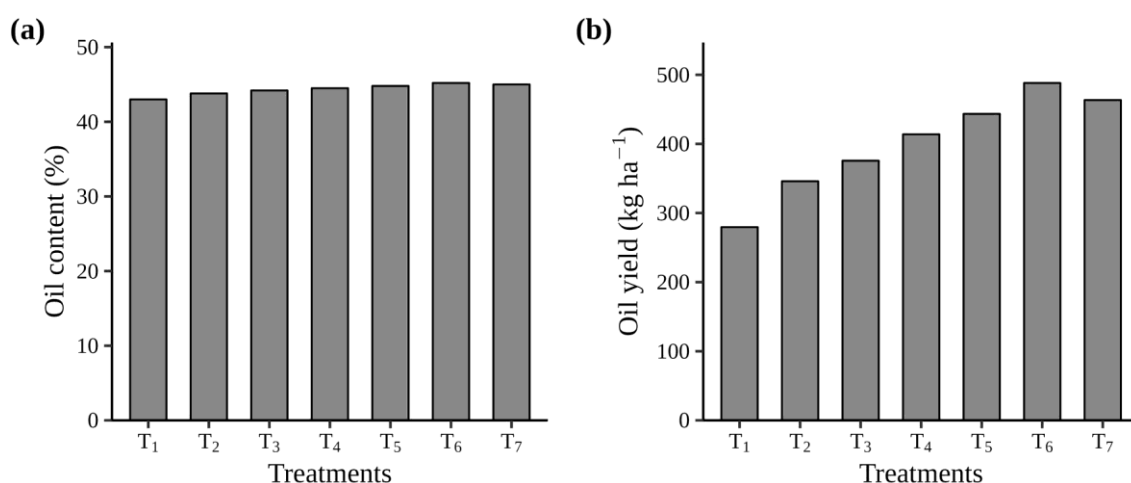


Figure 5. Effect of organic fertilizers on (a) oil content and (b) oil yield of sesame. T₁, control; T₂, FYM; T₃, vermicompost; T₄, recommended NPK; T₅, FYM + 50% NPK; T₆, FYM + 100% NPK; T₇, vermicompost + 50% NPK. Illustrative values; error bars ($\pm$ SE) and LSD letters to be added from measured data.

Discussion

Vegetative growth

Taller plants with thicker stems under integrated treatments are consistent with a complementary action of the two nutrient sources. Mineral fertilizer supplies readily available nitrogen and phosphorus during rapid early growth, while manures release nutrients more slowly and improve soil structure, water retention and biological activity (Diacono & Montemurro, 2010). The slight advantage of vermicompost over FYM may reflect its finer texture, faster mineralization and higher content of biologically active compounds. Comparable growth benefits from combining vermicompost and chemical fertilizer were found in sesame in Bangladesh (Shathi et al., 2023), and poultry manure with organic foliar sprays improved growth of summer sesame in India (Keshav et al., 2026).

Yield components

Capsules per plant showed the largest response of any trait, which agrees with its role as the main determinant of sesame yield. More branches create more flowering sites, and an adequate nutrient supply during flowering limits flower and capsule abortion. Seed number and seed weight are more strongly controlled by genotype, which explains their smaller responses. Integrated nitrogen

supply through organic resources likewise increased branches, capsules and seeds per capsule in earlier work (Takar et al., 2017), and vermicompost combined with gypsum improved sesame yield attributes at Latur (Bhandekar et al., 2023).

Biological yield and seed yield

The highest seed yield under FYM + 100% NPK is in line with the principle of INM, in which mineral fertilizer covers immediate crop demand and manure sustains supply later in the season. The near-constant harvest index shows that yield gains followed from greater biomass, a common pattern in sesame. Manure source and rate are known to affect nitrogen replacement value and sesame yield (Abd El Lateef et al., 2021), and co-applying animal and green manures increased sesame grain yield and total dry matter under organic management (Jalilian et al., 2022). The strong performance of vermicompost + 50% NPK is notable because it suggests that about half of the mineral fertilizer could be replaced with little loss of yield, as also reported by Ghosh et al. (2013) and Mandviwala et al. (2023). Not all studies agree: full inorganic fertilization gave the highest yield in Nagaland (Prabhumitra et al., 2026), which underlines the need to verify the replacement rate under local conditions.

Oil content and oil yield

Oil content is largely a varietal trait and usually changes only by a few percentage points with nutrition, whereas oil yield responds strongly through seed yield. Improved nutrient supply, particularly of nitrogen and sulphur, during seed filling can nonetheless raise oil concentration slightly. Higher oil content has been reported with chicken manure plus NPK on sandy soils (Nurhayati et al., 2024) and with castor cake plus 75% of the recommended dose (Mandviwala et al., 2023), whereas vermicompost alone gave the highest oil content in a pot study (Kurdiya et al., 2026). The treatment that maximizes oil concentration may therefore differ from the one that maximizes oil yield, and both traits should be analyzed separately.

Implications and limitations

Organic manures recycle farm nutrients and add organic matter, which is valuable on low-organic-matter soils in Sindh. Their composition varies widely, however, so application should be guided by soil tests and manure analysis rather than treated as an automatic substitute for mineral fertilizer (Baraki et al., 2025). Liquid organic formulations may also add to such programmes, although single-season results need confirmation (Surve et al., 2026). This study covers one season at one site; multi-season, multi-location trials and an economic analysis that includes the cost and availability of manure are needed before broad recommendations are made.

Conclusions

Combining organic manures with mineral fertilizer is expected to be the most effective way to raise sesame growth, seed yield and oil yield while maintaining soil fertility. In the illustrative dataset, FYM + 100% NPK gave the highest seed ($1,080 \text{ kg ha}^{-1}$) and oil yield (488.2 kg ha^{-1}), and vermicompost + 50% NPK came close while halving mineral fertilizer use. Gains in oil yield arise mainly from higher seed yield rather than higher oil concentration. A recommendation for farmers in Sindh will be made only after these effects are confirmed by statistical analysis of measured field data and supported by economic evaluation.

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