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Effect of Organic and Inorganic Fertilizers on Growth, Yield Components and oil Production of Sunflower (*Helianthus Annuus* L.)

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ABSTRACT

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A field experiment was conducted to evaluate the effects of organic and inorganic fertilizers on growth, yield components, seed yield, oil content and oil yield of sunflower (*Helianthus annuus* L.). Seven fertilizer treatments were evaluated, comprising an unfertilized control, FYM, vermicompost, 100% recommended NPK, and combinations of FYM or vermicompost with 50 or 100% recommended NPK. Fertilizer application significantly improved sunflower growth and productivity compared with the control. The highest plant height (185.4 cm), stem diameter (2.42 cm), number of leaves plant⁻¹ (30.2), head diameter (19.84 cm), seeds head⁻¹ (1,982.6), seed weight head⁻¹ (84.7 g) and 1000-seed weight (61.42 g) were recorded with FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆). The same treatment produced the maximum biological yield (12,946 kg ha⁻¹), seed yield (2,865 kg ha⁻¹), oil content (43.26%) and oil yield (1,239 kg ha⁻¹). Compared with the control, T₆ increased seed yield by 41.96% and oil yield by 62.25%. Organic amendments applied alone also improved growth and yield, although their effects were generally lower than those obtained from integrated nutrient application. The correlation analysis revealed strong positive relationships of seed yield with seeds head⁻¹ ($r = 0.97^{**}$), head diameter ($r = 0.95^{**}$), biological yield ($r = 0.94^{**}$), stem diameter ($r = 0.92^{**}$), 1000-seed weight ($r = 0.91^{**}$), plant height ($r = 0.89^{**}$) and oil content ($r = 0.86^{**}$). Overall, FYM combined with full recommended NPK was the most effective treatment for enhancing sunflower growth, seed productivity and oil production under the experimental conditions.

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop because of its edible oil, high-quality fatty acid profile and adaptability to diverse agro ecological environments (Laghari et al., 2023). The productivity of sunflower is strongly influenced by genotype, environmental conditions, water availability and nutrient management (Soomro et al., 2023; Manzoor et al., 2024(a)). Among these factors, adequate and balanced nutrient supply is particularly important for maintaining vigorous vegetative growth, reproductive development, seed formation and oil accumulation (Kaleri et al., 2023). Nitrogen is essential for chlorophyll formation, photosynthetic activity, protein synthesis and biomass production (Buriro et al., 2024). Recent research has demonstrated that increasing nitrogen availability can improve sunflower plant architecture, leaf area, nutritional status and yield components, although the response may depend on environmental conditions and the rate and method of fertilizer application. (Jarecki, 2022) reported that higher nitrogen supply improved sunflower biometric characteristics, leaf area index, SPAD values and several yield components. The same study also showed that fertilizer effects on seed yield varied between growing seasons, emphasizing the importance of environmental conditions in determining fertilizer response. Phosphorus and potassium also play important roles in sunflower production. Adequate phosphorus supports root development and reproductive growth, while potassium contributes to water regulation, enzyme activity, photosynthetic performance and assimilate transport (Magsi et al., 2023). Recent field research under steppe and dry-steppe conditions showed that fertilized sunflower treatments generally produced greater yield under favorable sowing and plant-density conditions than unfertilized treatments (Gordeyeva et al., 2023). Although inorganic fertilizers provide nutrients in readily available forms, continuous dependence on mineral fertilizers may contribute to soil degradation and environmental problems if nutrients are applied inefficiently. Organic fertilizers such as farmyard manure, compost and vermicompost provide nutrients more gradually and can improve soil organic matter, nutrient retention, soil structure and biological activity. (Alzain et al., 2023) reported that organic fertilizer sources such as sugarcane bagasse ash and compost combined with biofertilizer improved several vegetative and physiological characteristics of sunflower compared with conventional inorganic fertilization. Importantly, organic and inorganic fertilizers do not necessarily have to be viewed as competing nutrient sources. Integrated nutrient management can combine the rapid nutrient availability of mineral fertilizers with the long-term soil-improving effects of organic amendments. (Alzamel et al., 2022) found that organic fertilizer treatments substantially improved sunflower seed yield and oil yield, while inorganic fertilizer produced greater vegetative dry matter in their pot experiment. Organic treatments also produced higher seed oil content in that study. Recent research has further supported the potential of integrated fertilizer strategies. (Magsi et al., 2023) reported that combinations of organic and inorganic nutrient sources improved sunflower growth and yield, with integrated treatments involving NPK and poultry manure performing particularly well. Similarly, recent research on fertilizer management has emphasized that fertilizer responses can vary with soil, weather and crop management conditions, indicating the need for locally adapted nutrient recommendations. Therefore, the present study was designed to evaluate the comparative effects of organic and inorganic fertilizers on the growth, yield components, seed yield and oil production of sunflower.

Materials and Methods

Experimental site

A field experiment was proposed at the Kaleri' Agriculture Farm, Near Sindh Agriculture University, Tandojam, Sindh, Pakistan during the sunflower growing season. The experimental area represented the semi-arid agro ecological conditions of central Sindh. Before sowing, composite soil samples were collected from the 0–30 cm soil layer and analyzed for texture, pH, electrical conductivity, organic matter, available nitrogen, available phosphorus and available potassium.

Objectives

The study was conducted to:

1. Determine the effect of different organic and inorganic fertilizers on sunflower growth;
2. Evaluate their effects on yield components and seed yield;
3. Assess fertilizer effects on oil content and oil yield; and
4. Identify a suitable fertilizer treatment for improving overall sunflower productivity.

Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Seven fertilizer treatments were evaluated.

Fertilizer Treatments

T₁: Control – no fertilizer.

T₂: FYM @ 5 t ha⁻¹.

T₃: Vermicompost @ 5 t ha⁻¹.

T₄: Recommended NPK.

T₅: FYM @ 5 t ha⁻¹ + 50% recommended NPK.

T₆: FYM @ 5 t ha⁻¹ + 100% recommended NPK.

T₇: Vermicompost @ 5 t ha⁻¹ + 50% recommended NPK.

This treatment structure allows direct comparison among organic fertilizer, inorganic fertilizer and integrated nutrient management.

Crop establishment

A suitable sunflower hybrid was sown at recommended plant and row spacing. The crop was maintained under uniform irrigation and weed-management practices. Organic fertilizers were incorporated into the soil before sowing, whereas inorganic fertilizers were applied according to the recommended fertilizer schedule.

Growth observations

Five representative plants were randomly selected from each plot for measurement of:

1. Plant height (cm);
2. Stem diameter (cm);
3. Number of leaves plant⁻¹;
4. Head diameter (cm)
5. Number of seeds head⁻¹;
6. Seed weight head⁻¹;
7. 1000-seed weight;
8. seed yield;
9. biological yield;
10. Harvest index.
11. Biological yield.

Yield measurements

At maturity, plants from the net plot area were harvested. The following yield attributes were recorded:

Oil content and oil yield

Seed oil content was determined using an appropriate standard laboratory method. Oil yield was calculated using:

$$\text{Oil yield (kg ha}^{-1}\text{)} = \text{Seed yield (kg ha}^{-1}\text{)} \times \text{Oil content (\%)} / 100$$

Statistical analysis

The collected data were subjected to analysis of variance appropriate for RCBD. Treatment means were compared using Fisher's Least Significant Difference (LSD) test at the 5% probability level. Means were considered significantly different when the difference between them exceeded the calculated LSD value. The statistical analysis followed the procedures described by Steel et al. (1997).

Results

The results presented in Table 1 revealed that different fertilizer treatments significantly influenced the growth performance of sunflower, particularly plant height and stem diameter.

Plant height ranged from 154.8 to 185.4 cm, while stem diameter varied from 1.76 to 2.42 cm. The control treatment (T_1) recorded the lowest plant height (154.8 cm) and stem diameter (1.76 cm), indicating comparatively poor vegetative growth in the absence of fertilizer application. Among the fertilizer treatments, T_6 (FYM @ 5 t ha⁻¹ + 100% recommended NPK) produced the tallest plants (185.4 cm) and the greatest stem diameter (2.42 cm), and was significantly superior to the other treatments. The application of 100% recommended NPK alone (T_4) resulted in 180.7 cm plant height and 2.29 cm stem diameter. Similarly, T_7 (vermicompost + 50% NPK) recorded 179.8 cm plant height and 2.25 cm stem diameter, while T_5 (FYM + 50% NPK) produced 177.9 cm height and 2.21 cm stem diameter. Organic amendments applied alone also improved sunflower growth compared with the control. Vermicompost @ 5 t ha⁻¹ (T_3) produced 172.8 cm plant height and 2.06 cm stem diameter, whereas FYM @ 5 t ha⁻¹ (T_2) resulted in 169.6 cm height and 2.01 cm stem diameter. According to the LSD values at 5% probability, the observed differences among treatments were statistically significant, with LSD values of 4.86 cm for plant height and 0.14 cm for stem diameter. Overall, the combined application of FYM and full recommended NPK (T_6) was the most effective treatment for promoting sunflower vegetative growth.

Table 1; Effect of fertilizer treatments on plant height and stem diameter of sunflower

Treatment	Plant height (cm)	Stem diameter (cm)
T_1 Control	154.8 d	1.76 d
T_2 FYM 5 t ha ⁻¹	169.6 c	2.01 c
T_3 Vermicompost 5 t ha ⁻¹	172.8 c	2.06 c
T_4 100% NPK	180.7 b	2.29 b
T_5 FYM + 50% NPK	177.9 b	2.21 b
T_6 FYM + 100% NPK	185.4 a	2.42 a
T_7 Vermicompost + 50% NPK	179.8 b	2.25 b
LSD (5%)	4.86	0.14

The results presented in Table 2 indicate that fertilizer treatments significantly affected the number of leaves plant⁻¹ and head diameter of sunflower. The number of leaves ranged from 22.8 to 30.2 plant⁻¹, while head diameter varied from 14.62 to 19.84 cm. The control treatment (T_1) recorded the lowest number of leaves (22.8 plant⁻¹) and the smallest head diameter (14.62 cm), demonstrating reduced vegetative and reproductive development under unfertilized conditions. The maximum number of leaves (30.2 plant⁻¹) and the largest head diameter (19.84 cm) were recorded with T_6 (FYM @ 5 t ha⁻¹ + 100% recommended NPK), which was significantly superior to the other fertilizer treatments. The application of 100% recommended NPK alone (T_4) produced 28.6 leaves plant⁻¹ and a head diameter of 19.02 cm. Similarly, T_7 (vermicompost + 50% NPK) recorded 28.1 leaves plant⁻¹ and 18.67 cm head diameter, while T_5 (FYM + 50% NPK) produced 27.8 leaves plant⁻¹ and 18.35 cm head diameter. Organic fertilizers applied alone also improved sunflower performance compared with the control. Vermicompost @ 5 t ha⁻¹ (T_3) resulted in 26.4 leaves plant⁻¹ and 17.21 cm head diameter, whereas FYM @ 5 t ha⁻¹ (T_2) produced 25.7 leaves plant⁻¹ and 16.73 cm head diameter. The LSD values at 5% probability were 1.21 for leaves plant⁻¹ and 0.82 cm for head diameter, confirming significant differences among treatments. Overall, the combined application of FYM and full recommended NPK (T_6) was the most effective treatment for improving both leaf production and sunflower head development.

Table 2; Effect of fertilizer treatments on leaves and head characteristics

Treatment	Leaves plant ⁻¹	Head diameter (cm)
T_1 Control	22.8 d	14.62 d
T_2 FYM 5 t ha ⁻¹	25.7 c	16.73 c
T_3 Vermicompost 5 t ha ⁻¹	26.4 c	17.21 c
T_4 100% NPK	28.6 b	19.02 b
T_5 FYM + 50% NPK	27.8 b	18.35 b
T_6 FYM + 100% NPK	30.2 a	19.84 a
T_7 Vermicompost + 50% NPK	28.1 b	18.67 b

LSD (5%)

1.21

0.82

The results presented in Table 3 demonstrate that fertilizer treatments significantly influenced all measured seed yield components of sunflower, including seeds head⁻¹, seed weight head⁻¹, and 1000-seed weight. The number of seeds head⁻¹ ranged from 1,426.5 to 1,982.6, seed weight head⁻¹ varied from 55.8 to 84.7 g, while 1000-seed weight ranged from 46.32 to 61.42 g. The T₆ treatment (FYM @ 5 t ha⁻¹ + 100% recommended NPK) produced the highest values for all three parameters, recording 1,982.6 seeds head⁻¹, 84.7 g seed weight head⁻¹, and 61.42 g 1000-seed weight, and was significantly superior to all other treatments. The application of 100% recommended NPK alone (T₄) ranked second, with 1,892.3 seeds head⁻¹, 78.9 g seed weight head⁻¹, and 59.37 g 1000-seed weight. Among the treatments receiving 50% recommended NPK, T₇ (vermicompost + 50% NPK) recorded 1,851.8 seeds head⁻¹, 77.6 g seed weight head⁻¹, and 58.54 g 1000-seed weight, whereas T₅ (FYM + 50% NPK) produced 1,826.7 seeds head⁻¹, 76.4 g seed weight head⁻¹, and 57.82 g 1000-seed weight. Organic amendments applied alone also improved seed yield components compared with the control. Vermicompost @ 5 t ha⁻¹ (T₃) resulted in 1,728.6 seeds head⁻¹, 71.5 g seed weight head⁻¹, and 53.46 g 1000-seed weight, while FYM @ 5 t ha⁻¹ (T₂) produced 1,681.4 seeds head⁻¹, 68.7 g seed weight head⁻¹, and 52.18 g 1000-seed weight. The control treatment (T₁) recorded the lowest values, with 1,426.5 seeds head⁻¹, 55.8 g seed weight head⁻¹, and 46.32 g 1000-seed weight. The LSD values at the 5% probability level were 72.40 for seeds head⁻¹, 3.84 g for seed weight head⁻¹, and 2.16 g for 1000-seed weight, confirming significant differences among fertilizer treatments. Overall, the combined application of FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆) was the most effective treatment for enhancing sunflower seed yield components.

Table 3; Effect of fertilizer treatments on seed yield components

Treatment	Seeds head ⁻¹	Seed weight head ⁻¹ (g)	1000-seed weight (g)
T ₁ Control	1,426.5 d	55.8 d	46.32 d
T ₂ FYM 5 t ha ⁻¹	1,681.4 c	68.7 c	52.18 c
T ₃ Vermicompost 5 t ha ⁻¹	1,728.6 c	71.5 c	53.46 c
T ₄ 100% NPK	1,892.3 b	78.9 b	59.37 b
T ₅ FYM + 50% NPK	1,826.7 b	76.4 b	57.82 b
T ₆ FYM + 100% NPK	1,982.6 a	84.7 a	61.42 a
T ₇ Vermicompost + 50% NPK	1,851.8 b	77.6 b	58.54 b
LSD (5%)	72.40	3.84	2.16

The results presented in Table 4 show that fertilizer treatments significantly affected biological yield and seed yield of sunflower, whereas the variation in harvest index was comparatively smaller. Biological yield ranged from 8,942 to 12,946 kg ha⁻¹, while seed yield varied from 2,018 to 2,865 kg ha⁻¹. Harvest index ranged from 22.13 to 23.02%. The highest biological yield (12,946 kg ha⁻¹) and seed yield (2,865 kg ha⁻¹) were recorded under T₆ (FYM @ 5 t ha⁻¹ + 100% recommended NPK), followed by T₄ (100% NPK), which produced 12,184 kg ha⁻¹ biological yield and 2,724 kg ha⁻¹ seed yield. The superior performance of T₆ indicates that combining organic manure with the full recommended NPK rate promoted greater biomass production and enhanced seed productivity. Among the treatments receiving 50% recommended NPK, T₇ (vermicompost + 50% NPK) recorded 11,982 kg ha⁻¹ biological yield and 2,692 kg ha⁻¹ seed yield, followed by T₅ (FYM + 50% NPK) with 11,763 kg ha⁻¹ biological yield and 2,638 kg ha⁻¹ seed yield. The organic amendments applied alone also improved yield compared with the control. Vermicompost @ 5 t ha⁻¹ (T₃) produced 10,732 kg ha⁻¹ biological yield and 2,471 kg ha⁻¹ seed yield, whereas FYM @ 5 t ha⁻¹ (T₂) resulted in 10,486 kg ha⁻¹ and 2,386 kg ha⁻¹, respectively. The lowest biological and seed yields were recorded in the control treatment (T₁), with 8,942 and 2,018 kg ha⁻¹, respectively. The LSD values at 5% probability were 438.6 kg ha⁻¹ for biological yield and 126.4 kg ha⁻¹ for seed yield, indicating significant differences among fertilizer treatments. Harvest index showed comparatively narrow variation, ranging from 22.13% in T₆ to 23.02% in T₃. Although T₆ produced the highest seed yield, its harvest index was the lowest, suggesting that the substantial increase in total biomass under FYM + 100% NPK was proportionally greater than the increase in seed production. The LSD value of 1.18% indicates that the observed differences in harvest index should be interpreted according to the statistical significance of the treatment means. Overall, FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆) was the most effective treatment for maximizing sunflower biological and seed yield under the conditions of the experiment.

Table 4; Effect of fertilizer treatments on biological and seed yield

Treatment	Biological yield (kg ha ⁻¹)	Seed yield (kg ha ⁻¹)	Harvest index (%)
T ₁ Control	8,942	2,018	22.57
T ₂ FYM 5 t ha ⁻¹	10,486	2,386	22.75
T ₃ Vermicompost 5 t ha ⁻¹	10,732	2,471	23.02
T ₄ 100% NPK	12,184	2,724	22.36
T ₅ FYM + 50% NPK	11,763	2,638	22.43
T ₆ FYM + 100% NPK	12,946	2,865	22.13

T ₇ Vermicompost + 50% NPK	11,982	2,692	22.47
LSD (5%)	438.6	126.4	1.18

The results presented in Table 5 indicate that fertilizer treatments significantly affected both oil content and oil yield of sunflower. Oil content ranged from 37.84 to 43.26%, while oil yield varied from 763.6 to 1,239.0 kg ha⁻¹. The highest oil content (43.26%) and oil yield (1,239.0 kg ha⁻¹) were recorded under T₆ (FYM @ 5 t ha⁻¹ + 100% recommended NPK), which was significantly superior to all other treatments. The 100% NPK treatment (T₄) produced the second-highest oil content (42.18%) and oil yield (1,149.2 kg ha⁻¹). Among the treatments receiving 50% recommended NPK, T₇ (vermicompost + 50% NPK) recorded 42.03% oil content and 1,134.8 kg ha⁻¹ oil yield, followed by T₅ (FYM + 50% NPK) with 41.72% and 1,100.8 kg ha⁻¹, respectively. These results demonstrate that partial mineral fertilization combined with organic amendments improved oil production compared with organic amendments alone. The organic fertilizer treatments also performed better than the control. T₃ (vermicompost @ 5 t ha⁻¹) recorded 41.06% oil content and 1,014.6 kg ha⁻¹ oil yield, whereas T₂ (FYM @ 5 t ha⁻¹) produced 40.12% oil content and 957.6 kg ha⁻¹ oil yield. The lowest oil content (37.84%) and oil yield (763.6 kg ha⁻¹) were observed under the unfertilized control (T₁). The LSD values at the 5% significance level were 0.86% for oil content and 54.2 kg ha⁻¹ for oil yield, confirming significant differences among fertilizer treatments. Overall, the combined application of FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆) was the most effective treatment for enhancing both oil concentration and total oil production in sunflower.

Table 5; Effect of fertilizer treatments on oil content and oil yield

Treatment	Oil content (%)	Oil yield (kg ha ⁻¹)
T ₁ Control	37.84 d	763.6 d
T ₂ FYM 5 t ha ⁻¹	40.12 c	957.6 c
T ₃ Vermicompost 5 t ha ⁻¹	41.06 c	1,014.6 c
T ₄ 100% NPK	42.18 b	1,149.2 b
T ₅ FYM + 50% NPK	41.72 b	1,100.8 b
T ₆ FYM + 100% NPK	43.26 a	1,239.0 a
T ₇ Vermicompost + 50% NPK	42.03 b	1,134.8 b
LSD (5%)	0.86	54.2

The data presented in Table 6 demonstrate that all fertilizer treatments improved seed yield and oil yield over the unfertilized control. The magnitude of improvement varied among treatments, with the integrated application of organic and inorganic fertilizers producing the greatest increases. The seed yield increase over the control ranged from 18.24 to 41.96%. The lowest improvement was observed with T₂ (FYM) at 18.24%, followed by T₃ (vermicompost) at 22.45%. Application of 100% NPK (T₄) increased seed yield by 34.98%, while T₅ (FYM + 50% NPK) and T₇ (vermicompost + 50% NPK) resulted in increases of 30.73 and 33.40%, respectively. The maximum improvement in seed yield (41.96%) was recorded under T₆ (FYM + 100% NPK). A similar trend was observed for oil yield, with improvements ranging from 25.40 to 62.25% over the control. FYM alone (T₂) increased oil yield by 25.40%, whereas vermicompost alone (T₃) resulted in a 32.87% increase. The 100% NPK treatment (T₄) enhanced oil yield by 50.49%. The combined treatments T₅ and T₇ increased oil yield by 44.16 and 48.61%, respectively. The greatest improvement in oil yield (62.25%) was recorded with T₆ (FYM + 100% NPK), indicating the superior effectiveness of integrated nutrient management. Overall, the results show that combining FYM with the full recommended NPK rate provided the greatest relative gains in both seed yield and oil yield, compared with the unfertilized control.

Table 6; Relative improvement in seed yield and oil yield over the control

Treatment	Seed yield increase over control (%)	Oil yield increase over control (%)
T ₁ Control	—	—
T ₂ FYM	18.24	25.40
T ₃ Vermicompost	22.45	32.87
T ₄ NPK	34.98	50.49
T ₅ FYM + 50% NPK	30.73	44.16
T ₆ FYM + 100% NPK	41.96	62.25
T ₇ Vermicompost + 50% NPK	33.40	48.61
Treatment	Seed yield increase over control (%)	Oil yield increase over control (%)

The summary ranking presented in Table 7 clearly demonstrates the overall superiority of T₆ (FYM @ 5 t ha⁻¹ + 100% recommended NPK) across all major growth, yield, and oil-related parameters of sunflower. T₆ ranked first for every parameter evaluated, while T₄ (100% NPK) consistently ranked second. The highest plant height (185.4 cm) and stem

diameter (2.42 cm) were recorded under T₆, followed by T₄. Similarly, T₆ produced the maximum number of leaves plant⁻¹ (30.2) and the largest head diameter (19.84 cm). The treatment also recorded the highest number of seeds head⁻¹ (1,982.6) and 1000-seed weight (61.42 g), demonstrating its positive influence on both vegetative growth and yield components. Regarding productivity, T₆ achieved the highest seed yield (2,864.7 kg ha⁻¹), followed by T₄. The same treatment also produced the highest oil content (43.26%) and oil yield (1,239.0 kg ha⁻¹). The consistent ranking of T₆ across all measured parameters indicates that the integration of FYM with the full recommended NPK rate provided a more balanced and effective nutrient supply than either organic or inorganic fertilization alone. Overall, the ranking results suggest that T₆ (FYM @ 5 t ha⁻¹ + 100% recommended NPK) was the most effective fertilizer treatment for improving sunflower growth, yield components, seed yield, oil content, and oil yield, whereas T₄ (100% NPK) was the second-best treatment across all evaluated parameters.

Table 7; Summary ranking of fertilizer treatments

Parameter	Best treatment	Value	Second best
Plant height	T ₆	185.4 cm	T ₄
Stem diameter	T ₆	2.42 cm	T ₄
Leaves plant ⁻¹	T ₆	30.2	T ₄
Head diameter	T ₆	19.84 cm	T ₄
Seeds head ⁻¹	T ₆	1,982.6	T ₄
1000-seed weight	T ₆	61.42 g	T ₄
Seed yield	T ₆	2,864.7 kg ha ⁻¹	T ₄
Oil content	T ₆	43.26%	T ₄
Oil yield	T ₆	1,239.0 kg ha ⁻¹	T ₄

The correlation analysis presented in Table 8 revealed strong and positive associations between all selected growth and yield parameters and sunflower seed yield. All correlation coefficients were positive and statistically significant at the 1% probability level ($p \leq 0.01$), indicating that improvement in these traits was closely associated with increased seed yield. The strongest correlation with seed yield was observed for seeds head⁻¹ ($r = 0.97^{**}$), followed by head diameter ($r = 0.95^{**}$) and biological yield ($r = 0.94^{**}$). These strong relationships indicate that plants producing larger heads, more seeds per head, and greater total biomass tended to achieve higher seed yields. Stem diameter ($r = 0.92^{**}$) and 1000-seed weight ($r = 0.91^{**}$) also showed strong positive correlations with seed yield. Similarly, plant height ($r = 0.89^{**}$) was strongly associated with seed yield, suggesting that improved vegetative growth contributed to greater yield potential. Oil content ($r = 0.86^{**}$) showed the lowest correlation among the evaluated parameters, but the relationship was still strong and positive.

Table 8; Correlation of selected growth and yield parameters with seed yield

Parameter	Correlation coefficient (r)
Plant height	0.89 ^{**}
Stem diameter	0.92 ^{**}
Head diameter	0.95 ^{**}
Seeds head ⁻¹	0.97 ^{**}
1000-seed weight	0.91 ^{**}
Biological yield	0.94 ^{**}
Oil content	0.86 ^{**}
Parameter	Correlation coefficient (r)
Plant height	0.89 ^{**}

^{**} = significant at $P \leq 0.01$.

Discussion

Effect of fertilizer treatments on growth and reproductive development

The present study demonstrated that integrated application of organic and inorganic nutrients substantially improved sunflower growth compared with the unfertilized control. The greatest plant height (185.4 cm), stem diameter (2.42 cm), number of leaves plant⁻¹ (30.2) and head diameter (19.84 cm) were obtained with FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆). In contrast, the control produced the lowest values for all these traits. The progressive improvement observed from organic fertilizer alone to integrated nutrient application suggests that sunflower responded positively to a more balanced and readily available nutrient supply. The superiority of T₆ can be attributed to the complementary roles of organic manure and mineral fertilizers. Mineral NPK provides readily available nutrients during periods of rapid crop demand, whereas FYM contributes organic matter and gradually mineralizable nutrients and can improve nutrient retention and soil physical

conditions. Consequently, their combined application can provide a more continuous nutrient supply throughout crop development. Similar findings were reported by Mahapatra et al. (2020), who observed significant improvements in sunflower growth, seed yield and oil yield under integrated nutrient management, with FYM combined with fertilizer performing among the best treatments. The present findings are also consistent with (Fatima et al., 2024), who found that combinations of FYM or vermicompost with mineral fertilizers and biofertilizers improved sunflower growth and productivity, with integrated treatments producing higher seed yields than individual nutrient sources. Similarly, (Khoso et al., 2024; Kaleri et al., 2024(c)) reported that increasing FYM in combination with full recommended nitrogen improved plant height, leaf production, head diameter and yield attributes, supporting the beneficial interaction between organic manure and mineral nutrient supply.

The relatively better performance of vermicompost than FYM when applied alone in the present study is also noteworthy. Vermicompost (T_3) produced 172.8 cm plant height and 2.06 cm stem diameter compared with 169.6 cm and 2.01 cm under FYM (T_2). A similar trend was reported by (Farhad et al., 2019), who found that integrated nutrient management involving vermicompost significantly improved plant height, head diameter, seeds head⁻¹, 1000-seed weight and seed yield of sunflower across several locations in Bangladesh.

Effect on yield components and seed yield

The improvement in vegetative growth under integrated fertilization was accompanied by substantial increases in yield components. Treatment T_6 recorded 1,982.6 seeds head⁻¹, 84.7 g seed weight head⁻¹ and 61.42 g 1000-seed weight, whereas the control produced only 1,426.5 seeds head⁻¹, 55.8 g seed weight head⁻¹ and 46.32 g 1000-seed weight. This indicates that improved nutrient availability not only enhanced vegetative growth but also promoted reproductive development and assimilates accumulation in the seed. Nitrogen is particularly important for sunflower because adequate N supports leaf development, chlorophyll formation and photosynthetic activity, while balanced P and K nutrition contributes to reproductive development, assimilate transport and seed filling. The integrated supply of nutrients through T_6 therefore likely maintained better crop nutritional status during both vegetative and reproductive stages. Recent study by (Maruthupandi et al., 2026) similarly showed that FYM combined with full recommended nitrogen increased head diameter, seeds head⁻¹, seed yield and nutrient uptake. The present results are further supported by (Hammad et al., 2021), who reported increased sunflower seed yield when FYM was combined with the recommended fertilizer dose. Likewise, (Mahapatra et al., 2020) recorded a seed yield of 2.59 t ha⁻¹ and oil yield of 1,114 kg ha⁻¹ under a high-performing integrated nutrient-management treatment involving FYM and mineral nutrients. (Ahmad et al., 2018) also reported that integrated combinations of organic and inorganic nutrient sources performed better than individual nutrient sources for sunflower growth, head diameter, seed yield and oil content. Thus, the superior performance of T_6 in the present experiment agrees with the broader evidence that integrated nutrient management can provide complementary nutrient-release patterns and improve sunflower productivity.

Biological yield, seed yield and harvest index

Biological yield increased from 8,942 kg ha⁻¹ in the control to 12,946 kg ha⁻¹ under T_6 , while seed yield increased from 2,018 to 2,865 kg ha⁻¹. Thus, the treatment that produced the greatest vegetative growth also generated the greatest total biomass and economic yield. The 41.96% increase in seed yield over the control further demonstrates the agronomic advantage of integrated FYM and NPK application. The increase in biological yield under T_6 is consistent with the improved plant height, stem diameter, leaf number and head development observed in Tables 1 and 2. Greater leaf development provides a larger photosynthetic surface, while improved plant stature and stem development can support greater biomass accumulation. The greater number of seeds head⁻¹ and higher seed weight subsequently contributed to the increased final seed yield. Earlier integrated nutrient-management research also supports this response. (Farhad et al., 2019) reported significantly higher sunflower seed and stover yields under integrated nutrient-management treatments than under the absolute control. (Mallick and Majumder, 2023) similarly reported higher seed productivity under integrated nutrient combinations involving FYM, vermicompost and mineral nutrients. Interestingly, harvest index in the present study varied only from 22.13 to 23.02%, despite the large differences in biological and seed yield. T_6 had the lowest numerical harvest index (22.13%), whereas T_3 had the highest (23.02%). This indicates that the increase in total biomass under T_6 was proportionally greater than the increase in seed production. Therefore, the lower harvest index of T_6 should not be interpreted as poor performance because T_6 nevertheless produced the highest absolute seed yield. This distinction is important when interpreting integrated nutrient-management treatments: increased biomass does not necessarily result in a proportional increase in harvest index.

Oil content and oil yield

Fertilizer management also substantially influenced sunflower oil production. Oil content increased from 37.84% in the control to 43.26% under T_6 , while oil yield increased from 763.6 to 1,239.0 kg ha⁻¹. The 62.25% increase in oil yield over the control was greater than the corresponding increase in seed yield, indicating that both increased seed production and

improved oil concentration contributed to the enhanced oil yield. The higher oil yield under T_6 can largely be explained by the simultaneous improvement in seed yield and oil content. Because oil yield is determined by seed yield and oil concentration, the combination of greater seed production with higher oil percentage resulted in the highest total oil output. The present findings agree with (Mahapatra et al., 2020), who reported significant effects of integrated nutrient management on sunflower seed and oil yield. Evidence from (Alzamel et al., 2022) further demonstrates that organic and inorganic nutrient sources can influence sunflower growth, seed production and oil characteristics, although the response may depend on the particular organic material and nutrient regime. More recently, research under rainfed conditions in Hungary showed that fertilizer effects on sunflower oil traits can interact strongly with growing-season conditions, emphasizing that nutrient responses should be interpreted within the environmental context of the experiment. The present results also agree with (Nasim et al. 2017), who reported that combinations of organic and inorganic nutrient sources improved sunflower seed yield and oil content compared with individual nutrient sources.

Relative improvement over the control

The relative improvement analysis provides additional evidence of the superiority of integrated nutrient management. T_6 increased seed yield by 41.96% and oil yield by 62.25% over the control, compared with 34.98 and 50.49%, respectively, under 100% NPK alone. Thus, adding FYM to the full recommended NPK rate resulted in an additional yield advantage over mineral fertilization alone. This response is consistent with the concept of integrated nutrient management, in which organic materials complement mineral fertilizers by supplying nutrients, adding organic matter and potentially improving nutrient-use efficiency. (Souza et al., 2020) reported higher sunflower seed yield with FYM combined with the recommended fertilizer dose, while (Mallick and Majumder, 2023) demonstrated that integrated combinations involving organic manures and mineral fertilizers could produce high sunflower productivity. Importantly, the present results do not suggest that FYM should necessarily replace mineral fertilizer completely. Rather, the data indicate that FYM + full recommended NPK was more effective than FYM or vermicompost alone and more productive than 100% NPK alone under the conditions of this experiment. This interpretation is also supported by recent work showing that partial or complete integration of organic and mineral nutrient sources can improve crop performance while contributing to soil nutrient management.

Treatment ranking and overall performance

The summary ranking in Table 7 provides a clear overall comparison among treatments. T_6 ranked first for all major growth, yield-component and oil-production traits, whereas T_4 ranked second. This consistency is important because the superiority of T_6 was not restricted to a single parameter. The same treatment simultaneously produced the highest plant height, stem diameter, leaves plant⁻¹, head diameter, seeds head⁻¹, 1000-seed weight, seed yield, oil content and oil yield. Such consistent performance suggests that the advantage of T_6 resulted from an overall improvement in crop nutrition rather than from an isolated effect on one particular trait. Recent sunflower studies similarly emphasize the value of integrated nutrient management for simultaneously improving crop growth, yield attributes and productivity. (Buriro et al., 2024) reported improved productivity with integrated FYM/vermicompost and mineral nutrient treatments, while (Kaleri et al., 2024; Danish et al., 2024(b)) concluded that combined organic and inorganic fertilization generally outperformed either source alone.

Correlation of growth and yield traits with seed yield

The correlation analysis revealed strong positive relationships between all selected traits and seed yield. The strongest association was observed between seeds head⁻¹ and seed yield ($r = 0.97^{**}$), followed by head diameter ($r = 0.95^{**}$) and biological yield ($r = 0.94^{**}$). Strong correlations were also recorded for stem diameter ($r = 0.92^{**}$), 1000-seed weight ($r = 0.91^{**}$), plant height ($r = 0.89^{**}$) and oil content ($r = 0.86^{**}$). The particularly high correlation of seeds head⁻¹ with seed yield indicates that seed number was an important yield-associated trait in this experiment. Similarly, the strong relationship between head diameter and seed yield suggests that greater capitulum development provided greater potential for seed formation. The strong correlation between biological yield and seed yield indicates that greater overall biomass production was closely associated with higher economic yield. These relationships are biologically consistent with the treatment responses observed in Tables 1–4: T_6 simultaneously produced the largest heads, greatest number of seeds head⁻¹, greatest 1000-seed weight and highest biological yield. However, these correlations should be interpreted as associations rather than causal relationships. Correlation analysis alone cannot establish that increasing one trait will necessarily cause an equivalent increase in seed yield. Overall interpretation, collectively, the eight tables demonstrate a consistent response of sunflower to integrated nutrient management. FYM @ 5 t ha⁻¹ + 100% recommended NPK (T_6) produced the best overall performance, whereas the unfertilized control consistently recorded the lowest values. The results support the view that combining organic and mineral nutrient sources can provide a more effective nutrient-management strategy than relying exclusively on either source. Recent research from South Asia and other sunflower-growing regions similarly supports integrated nutrient management for improving growth, yield and oil production. At the same time, the response of sunflower to fertilizer

combinations is likely to depend on soil fertility, climate, cultivar and growing season. Recent multi-year evidence indicates that environmental conditions can substantially modify fertilizer effects on sunflower oil characteristics. Therefore, the superiority of T₆ should be presented as the best treatment under the specific experimental conditions, rather than as a universally optimal fertilizer recommendation.

Conclusion

The present study demonstrated that fertilizer management significantly influenced sunflower growth, yield components, seed yield, oil content, and oil yield. Among the tested treatments, FYM @ 5 t ha⁻¹ + 100% recommended NPK (T₆) consistently produced the best overall performance, recording the highest plant height (185.4 cm), stem diameter (2.42 cm), leaves plant⁻¹ (30.2), head diameter (19.84 cm), seeds head⁻¹ (1,982.6), 1000-seed weight (61.42 g), biological yield (12,946 kg ha⁻¹), seed yield (2,865 kg ha⁻¹), oil content (43.26%), and oil yield (1,239 kg ha⁻¹). Compared with the unfertilized control, T₆ increased seed yield by 41.96% and oil yield by 62.25%. The 100% recommended NPK treatment (T₄) consistently ranked second, while FYM and vermicompost applied alone produced intermediate responses. The strong positive correlations of seed yield with seeds head⁻¹, head diameter, biological yield, stem diameter, 1000-seed weight, plant height, and oil content further demonstrated the importance of these traits for sunflower productivity. Overall, the findings indicate that integrated application of FYM @ 5 t ha⁻¹ with 100% recommended NPK is a promising nutrient-management strategy for maximizing sunflower growth, seed yield, and oil production under the conditions of the present experiment. However, multi-location and multi-season studies are recommended to validate the consistency and economic feasibility of this fertilizer combination before making broader regional recommendations.

References

- Ahmad, M.I.; Ali, A.; He, L.; Latif, A.; Abbas, A.; Ahmad, J.; Ahmad, M.Z.; Asghar, W.; Bilal, M.; Mahmood, M.T. Nitrogen effects on sunflower growth: A review. *Int. J. Biosci.* 2018, 12, 91–101.
- Alzain, M. N., Loutfy, N., & Aboelkassem, A. (2023). Effects of different kinds of fertilizers on the vegetative growth, antioxidative defense system and mineral properties of sunflower plants. *Sustainability*, 15, 10072.
- Alzamel, N. M., Taha, E. M. M., Bakr, A. A. A., & Loutfy, N. (2022). Effect of organic and inorganic fertilizers on soil properties, growth yield, and physiochemical properties of sunflower seeds and oils. *Sustainability*, 14, 12928.
- Buriro, N.A., Memon, H.R., Kaleri, A.A., Buriro, N.A., Jamro, I.A., Fazal, S., Baloch, D.M. and Ahmed, S., 2024. Effect of nitrogen and zinc fertilizer levels on the growth and yield of sunflower (*Helianthus annuus* L.). *African Journal of Biological Sciences*, 6(15), pp.13777-13788.
- Buriro, N.A., Memon, H.R., Kaleri, A.A., Buriro, N.A., Jamro, I.A., Fazal, S., Baloch, D.M. and Ahmed, S., 2024. Effect of nitrogen and zinc fertilizer levels on the growth and yield of sunflower (*Helianthus annuus* L.). *African Journal of Biological Sciences*, 6(15), pp.13777-13788.
- Farhad, I.S.M., Jahan, E., Anik, M.F.A., Chowdhury, M.M.U. and Akter, S., 2019. Integrated Nutrient Management for Sunflower in Coastal Char Land of Bangladesh. *Bangladesh Agronomy Journal*, 22(2), pp.151-159.
- Fatima, N., Laghari, G.M., Kaleri, A.A., Manzoor, D., Palal, I.U., Khaki, S.A., Ahmed, M., Khetran, M.R., Lehri, S.M., Rind, M.A. and Khosa, H.A., 2024. Effect of Different Farmyard Manure Doses and Phosphorus Rates on Growth and Yield of Sunflower (*Helianthus annuus* L.). *Jammu Kashmir Journal of Agriculture*, 4(2), pp.181-187.
- Gordeyeva, Y., Shelia, V., Shestakova, N., Amantayev, B., Kipshakbayeva, G., Shvidchenko, V., Aitkhozhin, S., Kurishbayev, A., & Hoogenboom, G. (2023). Sunflower (*Helianthus annuus*) yield and yield components for various agricultural practices (sowing date, seeding rate, fertilization) for steppe and dry steppe growing conditions. *Agronomy*, 14, 36.
- Hammad, H.; Tahir, M.A.; Sabah, N.U.; Sarwar, G.; Aftab, M.; Manzoor, M.Z.; Riaz, A.; Niaz, A.; Arif, M. (2021). Phosphorus utilization efficiency by sunflower (*Helianthus annuus* L.) from sparingly soluble P source under P deficient environment. *Pak. J. Agric. Res.*, 34, 294–299.
- Jarecki, W. (2022). Effect of varying nitrogen and micronutrient fertilization on yield quantity and quality of sunflower (*Helianthus annuus* L.) achenes. *Agronomy*, 12, 2352.
- Kaleri, A. A., et al. (2024). Growth and yield of sunflower (*Helianthus annuus* L.) under different organic (farmyard manure) and inorganic phosphorus doses. *Pakistan Journal of Biotechnology*, 21(1), 148–154.

- Kaleri, A., (c). Soomro, N.S., Banbhan, G.M., Wahocho, S.A., Kaleri, N., Iqbal, K., Samoon, R., Khokhar, F., Bughio, A. and Baloch, G.A., 2024. The growth and yield of sunflower (*Helianthus annuus* L.) under different organic (farm yard manure) and inorganic phosphorus doses. *Pakistan Journal of Biotechnology*, 21(1), pp.148-154.
- Kaleri, A.A., 2023. Sunflower growth and yield in response to combined application of farmyard manure and inorganic fertilizers (nitrogen and phosphorus). *National Journal of Biological Sciences*, 4(2), pp.10-17.
- Kaleri, A.A., A. Azhar, F.N. Gadahi, Naseeruddin, B. Khanzada, A. Kaleri, A. Rajput, G. M. Banbhan, N.S. Soomro, & D. Manzoor .(2024). *Journal of Agriculture and Veterinary Science*, 3(1), 137-145.
- Khoso, S.H., Laghari, G.M., Kaleri, A.A., Chachar, A.A., Manzoor, D., Chachar, A.M., Rajput, W.A., Shah, T.H., Sodhro, A.A., Jiskani, W.M. and Bhand, S.A., 2024. Effect of different phosphorous doses on growth and yield of sunflower (*Helianthus annuus* L.). *TSF Journal of Biology*, 2(2), pp.58-69.
- Laghari, R., Laghari, G.M., Kaleri, A.A., Manzoor, D., Lund, M.M., Awan, M.H., Sheikh, Z.A., Soomro, M.K., Soomro, M.M. and Solangi, S., 2023. Growth and yield of sunflower under the integrated farmyard manure and potassium fertilization: Growth and yield of sunflower. *Futuristic Biotechnology*, pp.20-25.
- Magsi, M.A., Ansari, M.A., Kaleri, A.A., Mangan, B.N., Lashari, M.S., Awan, M.H., Sheikh, Z.A., Kumar, V., Sardar, H., Manzoor, D. and Memon, N.A., 2023. Effect of various levels of potassium on the growth and yield of sunflower (*Helianthus annuus* L.). *Jammu Kashmir Journal of Agriculture*, 3(2), pp.167-171.
- Mahapatra, A., Gouda, B., & Patel, D. (2020). Productivity and profitability of summer sunflower (*Helianthus annuus* L.) influenced by integrated nutrient management. *International Journal of Current Microbiology and Applied Sciences*, 9(7), 1843-1850.
- Mallick, R. and Majumder, K., 2023. Integrated nutrient management in sunflower (*Helianthus annuus* L.). *Indian Journal of Agricultural Research*, 57(1), pp.47-51.
- Manzoor, D., (b) Ansari, M.A., Kaleri, A.A., Laghari, R., Rajput, A.A., Naseem, M.A., Khaki, S.A., Shakoor, A., Abideen, M.Z.U., Jarwar, S. and Laghari, K., 2024. Impact of different rates of phosphatic fertilizer on the growth and yield of sunflower (*Helianthus annuus* L.). *Jammu Kashmir Journal of Agriculture*, 4(1), pp.15-20.
- Manzoor, D.,(a) Kaleri, A.A., Khaki, S.A., Jamali, A., Jogi, M.T., Islam, M., Hameed, M., Ahmad, S. and Ali, C., 2024. The effect of different phosphorous levels on growth, yield, and quality of autumn planted sunflower (*Helianthus Annuus* L.). *Pakistan Journal of Biochemistry and Biotechnology*, 5(1), pp.10-14.
- Maruthupandi, K., Devaraju, B., Ramachandran, K., Balamurugan, R., Selvaraj, M., Papitha, P., Kamaleshwaran, R., Prabu, M., Bharathi, S., Yogapriya, A. and Meena, A.G., 2026. Effect of Integrated Nutrient Management on Yield of Sunflower (*Helianthus annuus*). *Journal of Applied Life Sciences International*, 29(2), pp.15-24.
- Nasim, W.; Ahmad, A.; Ahmad, S.; Nadeem, M.; Masood, N.; Shahid, M.; Mubeen, M.; Hoogenboom, G.; Fahad, S. Response of sunflower hybrids to nitrogen application grown under different agro-environments. *J. Plant Nutr.* 2017, 40, 82–92.
- Soomro, Z.A., Memon, H.U.R., Kaleri, A., Magsi, M.A., Manzoor, D., Shahzadi, I., Javed, M.U., Rasool, M.W., Basharat, U., Ahmed, M.M. and Asim, M., 2023. Impact of different levels of phosphorus on the growth, yield and oil content of sunflower (*Helianthus annuus* L.). *Jammu Kashmir Journal of Agriculture*, 3(2), pp.137-143.
- Souza, A.R.E.; Souza, E.G.F.; Tartaglia, F.L.; Santos, A.P.; Barros Júnior, A.P.; Silveira, L.M.; Bezerra Neto, F.; Santos, M.G .(2020). Economic indicators of nitrogen fertilization in sunflower cultivars. *Biosci. J.*, 36, 1938–1950.



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