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EFFECT OF DIFFERENT COMBINATIONS OF ORGANIC AND INORGANIC FERTILIZER FOR MAXIMIZING YIELD AND OIL CONTENT OF SUNFLOWER

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Abstract

An experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University during the period from October 2021 to March 2022 with two factors, Factor A: Sunflower varieties(2): Viz., V_1= BARI Surjumukhi-2 and V_2 = BARI Surjumukhi-3; and Factor B: Application of different combination of organic and inorganic manures (5): Viz, F_1= Recommended dose of all chemical fertilizer (RDCF), F_2= Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3= Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4= Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5= Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6= Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7= Vermicompost @ 5 t ha^{-1} + 50% of RDCF to investigate the effect of different combinations of organic and inorganic fertilizer for maximizing yield and oil content of sunflower. The experiment was followed the Randomized complete block design (RCBD) with three replications. Results indicated that sunflower var. BARI Surjumukhi-2 consistently outperformed BARI Surjumukhi-3. The interaction effects revealed that BARI Surjumukhi-2 interaction with Vermicompost @ 5 t ha^{-1} + 75% of RDCF (V_1F_6) achieved the highest overall performance, with values such as head diameter (18.66 cm), number of seeds per head (437.23), 1000-seed weight (62.86 g), seed yield (2.87 t ha^{-1}), stover yield (7.86 t ha^{-1}), harvest index (26.82%), and seed oil content (40.77%). While the interaction of BARI Surjumukhi-3 with Cowdung @ 10 t ha^{-1} + 50% of RDCF resulted in the lowest values.

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop cultivated globally for its high-quality edible oil and other industrial applications. In Bangladesh, sunflower cultivation has gained popularity in recent years as a potential alternative to traditional oilseed crops like mustard and sesame. Organic fertilizers, derived from plant or animal sources, have gained increasing attention in recent years due to their potential to improve soil health, enhance nutrient availability, and promote sustainable agricultural practices. These fertilizers are rich in organic matter and slowly release nutrients, providing a steady supply of essential elements throughout the crop's growth cycle (Diacono and Montemurro, 2010). Organic sources contribute not only to the nutrient supply but also improve soil structure, water-holding capacity, and microbial activity, which can indirectly benefit plant growth and yield. Studies have shown that the application of organic fertilizers could significantly enhance sunflower yield and oil content, particularly in nutrient-depleted soils (Jat *et al.*, 2018).

Inorganic or synthetic fertilizers are formulated to provide readily available forms of essential nutrients, such as nitrogen, phosphorus, and potassium, to the plants. These fertilizers are often preferred for their consistent nutrient composition and their ability to deliver a quick nutrient boost to the crop during critical growth stages (Mirshekari *et al.*, 2022). In sunflower production, nitrogen is particularly important for vegetative growth and biomass accumulation, while phosphorus plays a vital role in root development, flowering, and seed formation. Potassium, on the other hand, enhances drought tolerance, disease resistance, and oil quality

(Abbas *et al*., 2021). The judicious application of inorganic fertilizers, considering the specific nutrient requirements of sunflower varieties, can significantly improve yield and oil content. However, excessive or imbalanced application of inorganic fertilizers can lead to environmental concerns, such as nutrient leaching and soil degradation (Guo *et al*., 2020).

The integration of organic and inorganic fertilizers, known as integrated nutrient management (INM), has been recognized as an effective approach to optimize crop productivity while maintaining soil health and environmental sustainability. The combined application of these fertilizers can provide a balanced supply of nutrients, leveraging the benefits of both organic and inorganic sources (Ghosh *et al*., 2021). Organic fertilizers contribute to soil fertility and structure, while inorganic fertilizers provide readily available nutrients to meet the immediate nutrient demands of the crop. The synergistic effect of this combination could lead to improved nutrient use efficiency, enhanced soil microbial activity, and better crop performance (Rezaei *et al*., 2021).

Materials and Methods

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka under the Agroecological zone of Modhupur Tract, AEZ-28 during the *Rabi* season from October to March 2022. The climate of the experimental site was subtropical, characterized by the winter season from November to February, and the pre-monsoon period from March to April, and the monsoon period from May to October (Edris *et al*., 1979). The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were two factors viz., Factor A: Sunflower varieties-2 (V_1 = BARI Surjumukhi-2 and V_2 = BARI Surjumukhi-3) and Factor B: Application of different combination of organic and inorganic manures-5 (F_1= Recommended dose of all chemical fertilizer (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF

The organic fertilizer doses were applied during the final land preparation for uniform distribution and incorporation into soil. For the inorganic fertilizers, the recommended dose of 60:90:60 kg of Nitrogen (N), Phosphorus oxide (P_2O_5), and Potassium oxide (K_2O) per hectare was applied in the form of urea, triple superphosphate (TSP), and muriate of potash, respectively. The application of inorganic fertilizers was split into two doses. The first dose, 50% nitrogen (N) and full doses of phosphorus (P) and potassium (K) was applied at sowing time. The remaining 50% nitrogen was top-dressed 30 days after sowing (DAS). Sowing of seed was done manually by line sowing on 12th October 2022 using a seed rate of 8-10 kg ha^{-1} by dibbling two seeds at each hill to a depth of 3 cm by maintaining the spacing at 60 cm × 30 cm at each. All intercultural operations like gap filling, hand weeding, irrigation, and plant protection measures were taken properly. Plant height (cm), dry weight plant^{-1} (g), head diameter (cm), number of seed head^{-1}, 1000-seed weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}), harvest index (t ha^{-1}), oil content (%) were recorded during the experiment. The harvest index was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{Grain\ Yield}{Biological\ Yield} \times 100\%$$

The data were analyzed and the means were separated by least significant difference (LSD) at 5% level of probability using the Statistix 10 data analysis software.

Results and Discussion

Plant height

The plant height of the sunflower was significantly influenced by the integration of different doses of organic and inorganic fertilizer (Fig. 1).

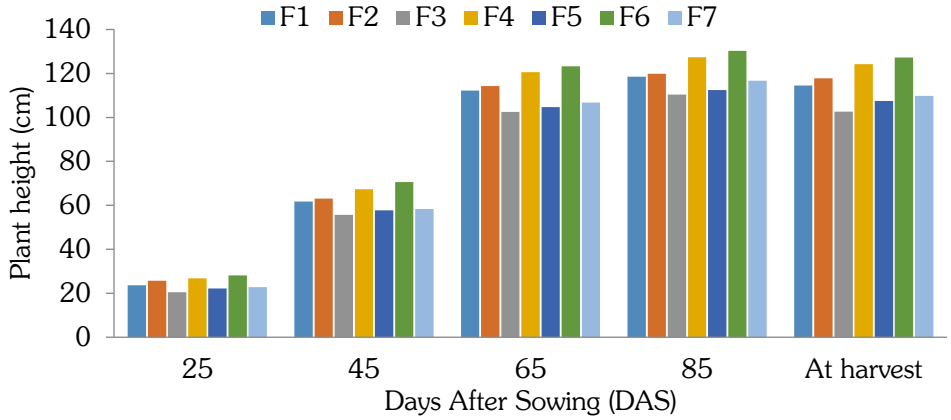

Fig. 1. Effect of integration of organic and inorganic fertilizer on plant height at different DAS of sunflower. Here, F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF. LSD $_{(0.05)}$ = 1.75, 4.57, 5.97, 7.64, and 6.96 at 25, 45, 65, and 85 DAS at harvest, respectively.

Experimental findings revealed that the maximum plant height of sunflower (28.07, 70.56, 123.29, 130.25, and 127.26 cm) at 25, 45, 65, 85 DAS, and at harvest, respectively, was observed in the F_6 (Vermicompost @ 5 t ha^{-1} + 75% of RDCF) treatment, which was statistically similar to the F_4 (26.84, 67.33, 120.57, 127.40, and 124.23 cm) at the same growth stages. In contrast, the lowest plant height of was observed in the F_3 (Cowdung @ 10 t ha^{-1} + 50% of RDCF) treatment, which was statistically similar to F_5.

Table 1. Interaction effect of variety and integration of organic and inorganic fertilizer on plant height of sunflower on different DAS

Interaction	Plant height (cm)				
	25 DAS	45 DAS	65 DAS	85 DAS	At harvest
$V_1 \times F_1$	24.70 c-e	68.63 b-d	122.50 cd	131.35 bc	127.35 cd
$V_1 \times F_2$	26.89 bc	70.15 bc	125.01 bc	132.12 bc	130.85 bc
$V_1 \times F_3$	22.38 ef	61.54 ef	111.18 ef	126.55 cd	115.18 e-g
$V_1 \times F_4$	28.22 ab	74.50 ab	132.42 ab	140.60 ab	138.73 ab
$V_1 \times F_5$	24.67 c-e	64.57 c-e	113.37 e	127.75 cd	120.28 d-f
$V_1 \times F_6$	29.90 a	78.06 a	133.59 a	143.25 a	142.35 a
$V_1 \times F_7$	23.81 d-f	64.63 c-e	115.52 de	129.80 bc	122.97 c-e
$V_2 \times F_1$	22.66 ef	54.75 gh	101.98 h-i	105.75 fg	101.63 i-k
$V_2 \times F_2$	24.45 c-e	56.09 f-h	103.61 f-h	107.52 e-g	104.73 h-j
$V_2 \times F_3$	18.45 h	49.80 h	93.72 i	94.30 h	90.17 l
$V_2 \times F_4$	25.45 cd	60.16 e-g	108.71 e-g	114.20 ef	109.73 g-i
$V_2 \times F_5$	19.79 gh	50.85 h	95.88 hi	97.15 gh	94.60 k-l
$V_2 \times F_6$	26.25 b-d	63.05 de	112.98 e	117.25 de	112.16 f-h
$V_2 \times F_7$	21.70 fg	52.02 h	98.07 hi	103.58 f-h	96.65 j-l
LSD $_{(0.05)}$	2.47	4.46	8.44	10.80	9.84
CV (%)	6.08	6.21	4.39	5.39	5.11

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance. Here, V_1 = BARI Surjumukhi 2 and V_2 = BARI Surjumukhi 3; and F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Combining vermicompost with 75% RDCF provides an initial nutrient boost from chemical fertilizers for rapid growth, while vermicompost ensures sustained nutrient release. This approach enhances root development, nutrient uptake, and photosynthesis, leading to taller, more vigorous sunflower plants compared to using chemical or organic fertilizers alone.

Interaction effect of variety and integration of organic and inorganic fertilizer

The Plant height of sunflowers was significantly influenced on different DAS due to the interaction (Table 1). Experimental results showed that the maximum plant height (29.90, 78.06, 133.59, 143.25, and 142.35 cm) was observed in the V_1F_6 interaction treatment at 25, 45, 65, and 85 DAS which was statistically similar to V_1F_4 (28.22, 74.50, 132.42, 140.60 and 138.73cm) at the same intervals, including harvest. On the other hand, the V_2F_3 treatment recorded the lowest plant height.

Leaf area

The integration of different doses of organic and inorganic fertilizers significantly affects leaf area (Table 2). The experimental findings revealed that at 25, 40, 55, and 70 DAS, the maximum leaf area (3306.7, 14691, 22003, and 31852 mm) was observed in the V_1F_6 treatment, which was statistically similar to the V_1F_4**.** Applying 5 t ha^{-1} vermicompost with 75% RDCF enhances sunflower leaf area by combining gradual nutrient release with readily available fertilizers. This synergy supports continuous nutrient supply, promoting growth and yield. A similar result was also observed by Gahlot and Singh (2023), who reported that the integrated use of vermicompost and chemical fertilizers significantly influenced the leaf area of sunflowers. On the other hand, the V_2F_3 interaction treatment recorded the lowest leaf area followed by V_2F_5 and V_2F_7 at the same intervals.

Table 2. Interaction effect of variety and integration of organic and inorganic fertilizer on leaf area on different DAS of sunflower

Interaction	Leaf area plant^{-1} (mm^2) at			
	25 DAS	40 DAS	55 DAS	70 DAS
$V_1 \times F_1$	2793.2 b	12755 cd	19005 cd	28732 c
$V_1 \times F_2$	2793.0 b	13072 b-d	19527 b-d	29174 bc
$V_1 \times F_3$	2318.5 de	11850 de	17914 c-e	25972 de
$V_1 \times F_4$	3222.6 a	14162 ab	21265 ab	31319 ab
$V_1 \times F_5$	2604.3 b-d	12018 c-e	17959 c-e	26879 cd
$V_1 \times F_6$	3306.7 a	14691 a	22003 a	31852 a
$V_1 \times F_7$	2785.0 bc	12365 c-e	18307 c-e	27175 cd
$V_2 \times F_1$	2567.2 b-e	11981 de	17904 c-e	20475 hi
$V_2 \times F_2$	2607.5 b-d	12315 c-e	18179 c-e	21503 gh
$V_2 \times F_3$	2248.2 e	11122 e	16572 e	18932 i
$V_2 \times F_4$	2787.7 bc	12773 cd	19252 cd	23377 fg
$V_2 \times F_5$	2365.6 de	11299 e	17020 e	18466 i
$V_2 \times F_6$	2831.3 b	13279 bc	19720 bc	24091 ef
$V_2 \times F_7$	2466.3 c-e	11868 de	17681 de	19310 hi
$LSD_{(0.05)}$	325.15	1269.70	1906.30	2498.50
CV (%)	7.19	6.03	6.06	6.00

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance. Here, V_1 = BARI Surjumukhi 2 and V_2 = BARI Surjumukhi 3; and F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Dry weight of plant

Dry weight per plant varies due to different growth stages showed significant influence on different DAS, affected by different doses of organic and inorganic fertilizer (Table 3). Based on the experimental findings discovered that the V_1F_6 exhibited the highest dry weight per plant

(1.31, 19.85, 44.53, and 238.16 g) at 25, 50, 75, DAS and at harvest respectively. The result was consistent with the research conducted by Gahlot and Singh (2023). In contrast, the V_2F_3 interaction treatment resulted in the lowest dry weight per plant (which was statistically similar to the V_2F_5.

Table 3. Interaction effect of variety and integration of organic and inorganic fertilizer on dry weight plant^{-1} at different DAS of sunflower

Interaction	Dry weight plant^{-1} (g)			
	25 DAS	50 DAS	75 DAS	At harvest
$V_1 \times F_1$	1.04 cd	12.83 de	39.32 cd	210.36 b-d
$V_1 \times F_2$	1.08 c	14.19 cd	40.08 bc	214.28 bc
$V_1 \times F_3$	0.90 e	11.17 ef	33.28 e	201.38 c-f
$V_1 \times F_4$	1.14 bc	16.95 b	43.36 ab	224.26 ab
$V_1 \times F_5$	0.94 de	11.01 fg	35.20 e	204.30 c-f
$V_1 \times F_6$	1.31 a	19.85 a	44.53 a	238.16 a
$V_1 \times F_7$	0.97 de	12.31 ef	36.40 c-e	207.28 b-e
$V_2 \times F_1$	0.74 f	10.72 f-h	27.14 gh	188.65 e-h
$V_2 \times F_2$	0.93 e	11.57 ef	29.30 fg	191.32 d-h
$V_2 \times F_3$	0.54 h	7.93 i	24.10 h	174.39 h
$V_2 \times F_4$	1.09 c	14.70 c	32.91 ef	194.25 d-g
$V_2 \times F_5$	0.63 gh	9.16 hi	25.45 gh	180.56 gh
$V_2 \times F_6$	1.21 ab	16.57 b	35.57 de	199.26 c-g
$V_2 \times F_7$	0.67 fg	10.02 gh	26.34 gh	185.70 f-h
LSD $_{(0.05)}$	0.10	1.72	3.89	19.20
CV (%)	6.33	8.03	6.86	5.69

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance. Here, V_1 = BARI Surjumukhi 2 and V_2 = BARI Surjumukhi 3; and F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Head diameter

Variation in head diameter among sunflower varieties is attributed to their genetic composition. The integration of different sunflower varieties and the application of varying amounts of organic and inorganic fertilizers have shown significant impacts on the head diameter of sunflowers (Table 4). The maximum head diameter of sunflower (18.66 cm) was observed from the V_1F_6 which was statistically similar to the V_1F_4 (18.03 cm). In contrast, the V_2F_3 treatment recorded the lowest head diameter (13.15 cm).

Integrating vermicompost with chemical fertilizers provides balanced nutrients, including N, P, and K, throughout sunflower growth. Vermicompost releases these essential nutrients gradually, while chemical fertilizers support early growth. This continuous supply enhances flower bud initiation, pollination, and seed set, leading to larger heads. Vermicompost also improves soil structure, further boosting nutrient uptake and head development. This approach results in larger head diameters compared to using only organic or inorganic fertilizers. This is quite similar to the findings of Umar *et al*. (2017) who found that a 50:50 ratio of vermicompost and NPK increased head diameter, and seed weight head^{-1} of sunflower.

Number of seeds per head

The integrated use of various dosages of organic and inorganic fertilizer also had a significant impact on the number of seeds per sunflower head (Fig. 2). The highest number of seeds per head (412.50) was observed from the F_6 treated plot whereas the lowest number of seeds head^{-1} (273.21) was observed from the F_3 treated plot.

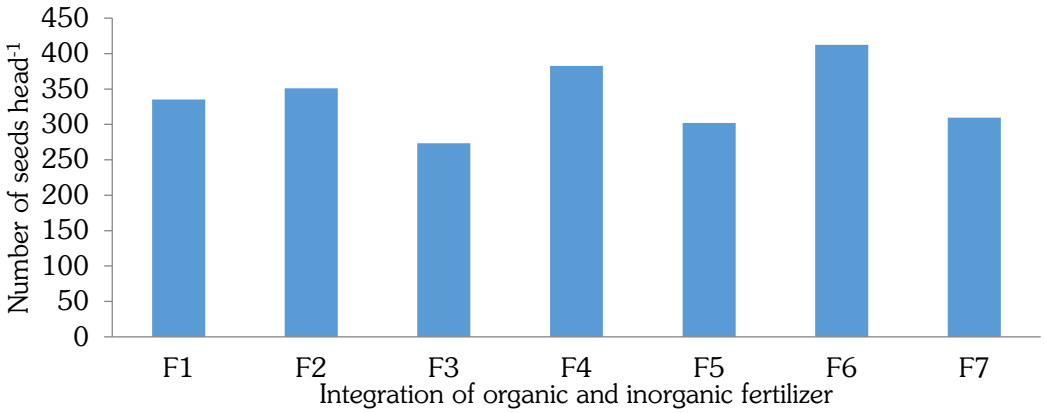

Fig. 2. Effect of integration of organic and inorganic fertilizer on the number of seeds head^{-1} of sunflower (LSD $_{(0.05)}$ = 26.90). Here, F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Interaction effect of variety and integration of organic and inorganic fertilizer

The number of seeds head^{-1} of sunflower was significantly affected by the integration of different sunflower varieties and the application of varying amounts of organic and inorganic fertilizer (Table 4). The interaction treatment V_1F_6 resulted in the maximum number of seeds head^{-1} (437.23), which was statistically similar to the V_1F_4 (412.15) and the lowest number of seeds head^{-1} (242.29) from the V_2F_3 interaction treatment.

Weight of 1000 seeds

The weight of 1000 sunflower seeds varied significantly across different sunflower varieties. The integrated use of organic and inorganic fertilizers significantly affected 1000- seed weight (Fig. 3). The maximum weight (59.98 g) was recorded in the F6 treated plot, which was statistically similar to the F4 (59.48 g) plot. The lowest weight (52.91 g) was observed in the F3 treated plot**,** similar to F5 (53.89 g**)** plot. A similar result was reported by Jayaprakash *et al.* (2011) who found that the application of 5 t ha^{-1} vermicompost + 75% NPK recorded the highest growth, yield attributes, and seed yield compared to other treatments.

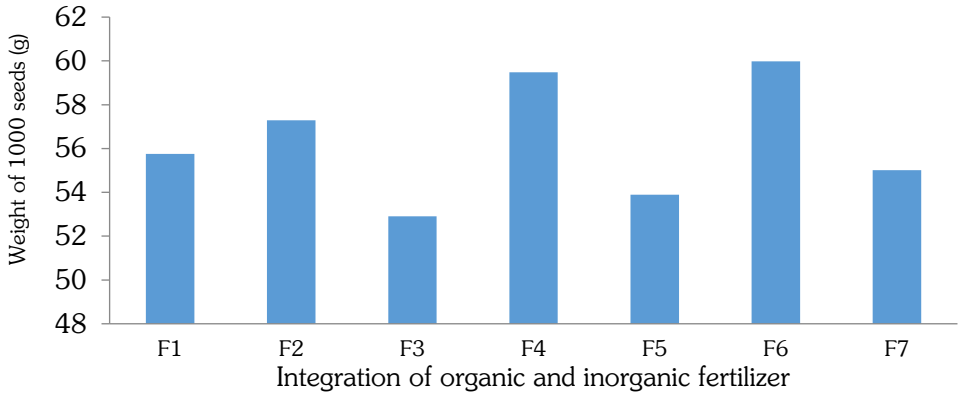

Fig. 3. Effect of integration of organic and inorganic fertilizer on weight of 100 seeds of sunflower (LSD $_{(0.05)}$ = 3.40). Here, F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Interaction effect of variety and integration of organic and inorganic fertilizer

The weight of 1000 -seeds of sunflower was significantly affected by the integration of different sunflower varieties and the application of varying amounts of organic and inorganic fertilizer (Table 4). The interaction treatment V_1F_6 resulted in the maximum weight of 1000-seeds of sunflower (62.86 g) which was statistically similar to the V_1F_4 (62.23 g) and V_1F_2 (60.10 g) whereas the lowest weight of 1000- seeds of sunflower (49.51g) from the V_2F_3 interaction treatment which was statistically similar to the V_2F_5 (50.67 g).

Table 4. Interaction effect of variety and integration of organic and inorganic fertilizer on head diameter, number of seeds head^{-1}, and weight of 1000- seeds of sunflower

Interaction	Head diameter (cm)	No. seeds head^{-1}	Weight of 1000 seed (g)
$V_1 \times F_1$	15.98 c-e	362.28 c-e	58.36 a-d
$V_1 \times F_2$	16.42 bc	382.35 b-d	60.10 a-c
$V_1 \times F_3$	14.25 d-g	304.12 gh	56.31 c-f
$V_1 \times F_4$	18.03 ab	412.15 ab	62.23 ab
$V_1 \times F_5$	14.85 c-g	338.44 e-f	57.10 c-f
$V_1 \times F_6$	18.66 a	437.23 a	62.86 a
$V_1 \times F_7$	15.07 c-g	346.53 d-f	57.65 b-e
$V_2 \times F_1$	15.05 c-g	308.27 gh	53.13 e-h
$V_2 \times F_2$	14.97 c-g	319.56 fg	54.49 d-g
$V_2 \times F_3$	13.15 g	242.29 i	49.51 h
$V_2 \times F_4$	15.50 c-f	353.33 c-f	56.73 c-f
$V_2 \times F_5$	13.78 fg	265.26 i	50.67 gh
$V_2 \times F_6$	16.25 b-d	387.77 bc	57.10 c-f
$V_2 \times F_7$	14.10 e-g	272.65 hi	52.37 f-h
$LSD_{(0.05)}$	2.04	38.04	4.812
CV (%)	7,89	6.71	5.09

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance. Here, V_1 = BARI Surjumukhi 2 and V_2 = BARI Surjumukhi 3; and F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Seed yield

The cultivation of different sunflower varieties significantly influences seed yield. The integration of organic and inorganic fertilizers at varying rates also significantly impacted sunflower seed yield (Fig. 4). The experimental results showed that the F_6 treated plot recorded the maximum seed yield (2.55 t ha^{-1}), which was statistically similar to plots treated with F_4 (2.43 t ha^{-1}). Conversely, the lowest seed yield (1.52 t ha^{-1}) was observed in the F_3 treated plot, which was statistically similar to plots treated with F_5 (1.56 t ha^{-1}).

Vermicompost supplies N, P, and K gradually, supporting growth, flowering, and seed development, whereas chemical fertilizers ensure an immediate supply of these nutrients. Their integration ensures a continuous nutrient supply, enhances soil structure, and boosts yield by supporting optimal plant growth and seed filling. The results align with the findings of Ahmad *et al*. (2018) who reported that integrated use of vermicompost (5 t ha^{-1}) and 75% recommended NPK increased sunflower seed yield by 35% over the control while also improving soil properties like organic carbon, available N, P and K status.

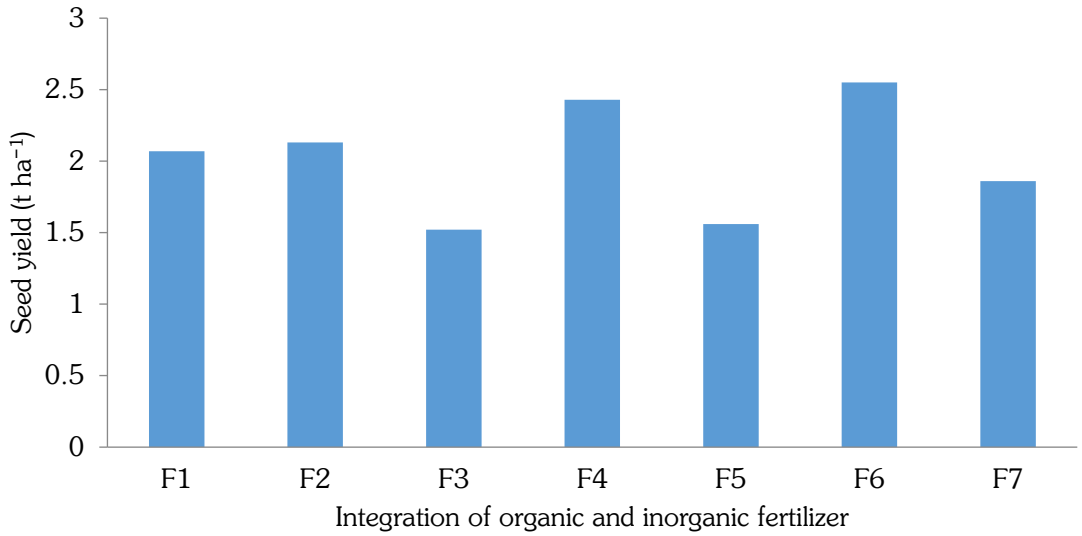

Fig. 4. Effect of integration of organic and inorganic fertilizer on seed yield of sunflower (LSD $_{(0.05)}$ = 0.15). Here, F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Interaction effect of variety and integration of organic and inorganic fertilizer

The seed yield of sunflower was significantly affected by the integration of different sunflower varieties and the application of varying amounts of organic and inorganic fertilizer (Table 5). The experimental findings indicate that the V_1F_6 interaction treatment resulted in the maximum seed yield of sunflower (2.87 t ha^{-1}) which was statistically similar to the V_1F_4 (2.76 t ha^{-1}) interaction treatment. Whereas the lowest seed of sunflower (1.31 t ha^{-1}) was observed from the V_2F_3 which was statistically similar with the V_2F_5 (1.43 t ha^{-1}), and V_2F_7 (1.52 t ha^{-1}) interaction treatment.

Stover yield

The V_1F_6 interaction treatment resulted in the maximum stover yield of sunflower (7.86 t ha^{-1}) which was statistically similar to the V_1F_4 (7.79 t ha^{-1}), V_1F_1 (7.55 t ha^{-1}) and V_1F_2 (7.56 t ha^{-1}) interaction treatment (Table 5). Whereas the lowest stover yield of sunflower (5.17 t ha^{-1}) was observed from the V_2F_3 which was statistically similar to the V_2F_5 (5.36 t ha^{-1}) and V_2F_7 (5.65 t ha^{-1}) interaction treatment.

Harvest index

The experimental result indicated that the plot treated with F_6 treatment had the maximum harvest index (25.67 %) of sunflower (Fig. 5) followed by F_4 (25.11%) for the harvest index of sunflowers. The lowest harvest index (21.55 %) was observed with F_3 treatment which was statistically similar to the F_5 (21.81%) and F_7 (22.20 %) treatment.

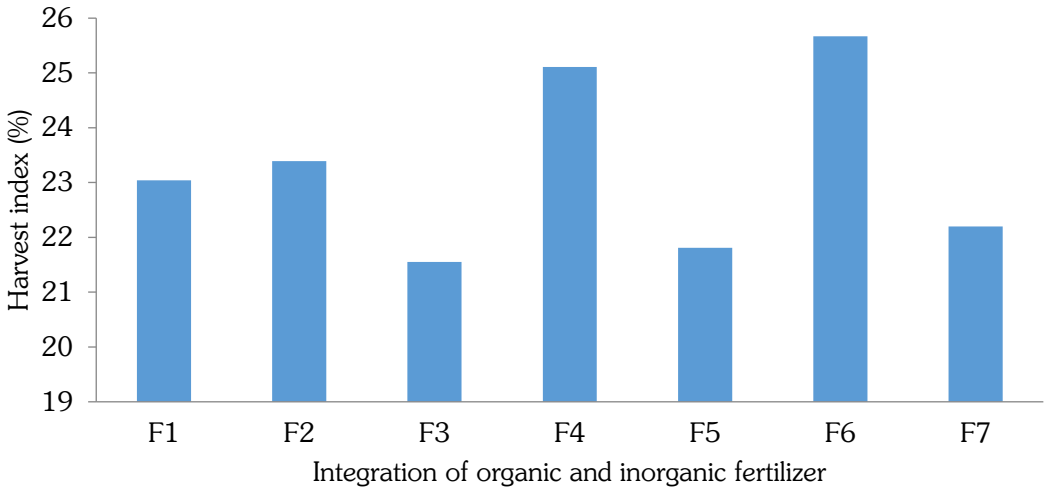

Fig. 5. Effect of integration of organic and inorganic fertilizer on harvest index of sunflower (LSD $_{(0.05)}$ = 1.43). Here, F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Oil content (%)

Cultivation of different varieties of sunflower along with the integration of organic and inorganic fertilizers had shown a non-significant impact on the oil content of sunflower (Table 5). The more nitrogen supply is available, the more seed yields are abundant but with less oil content.

Table 5. Interaction effect of variety and integration of organic and inorganic fertilizer on yield attributes, yield, harvest index and oil content of sunflower

Interaction	Seed yield (t ha^{-1})	Stover Yield (t ha^{-1})	Harvest index (%)	Oil content (%)
$V_1 \times F_1$	2.37 bc	7.55 ab	24.05 c-e	39.93
$V_1 \times F_2$	2.43 b	7.56 ab	24.32 b-d	40.02
$V_1 \times F_3$	1.73 ef	6.11 e-g	22.08 e-g	38.78
$V_1 \times F_4$	2.76 a	7.79 a	26.15 ab	40.56
$V_1 \times F_5$	1.69 ef	6.04 fg	22.56 c-g	38.91
$V_1 \times F_6$	2.87 a	7.86 a	26.82 a	40.77
$V_1 \times F_7$	2.19 cd	7.25 bc	23.18 c-f	39.08
$V_2 \times F_1$	1.77 e	6.23 ef	22.02 fg	39.00
$V_2 \times F_2$	1.82 e	6.29 ef	22.45 d-g	39.33
$V_2 \times F_3$	1.31 g	5.17 h	21.02 g	38.35
$V_2 \times F_4$	2.10 d	6.63 de	24.06 c-e	39.93
$V_2 \times F_5$	1.43 g	5.36 h	21.05 g	38.78
$V_2 \times F_6$	2.22 b-d	6.83 cd	24.52 bc	40.18
$V_2 \times F_7$	1.52 fg	5.65 gh	21.21 fg	38.90
LSD $_{(0.05)}$	0.22	0.52	2.03	NS
CV (%)	6.45	4.73	5.19	3.68

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance. Here, V_1 = BARI Surjumukhi 2 and V_2 = BARI Surjumukhi 3; and F_1 = Recommended dose of all chemical fertilizers (RDCF), F_2 = Cowdung @ 10 t ha^{-1} + 75% of RDCF, F_3 = Cowdung @ 10 t ha^{-1} + 50% of RDCF, F_4 = Poultry litter @ 5 t ha^{-1} + 75% of RDCF, F_5 = Poultry litter @ 5 t ha^{-1} + 50% of RDCF, F_6 = Vermicompost @ 5 t ha^{-1} + 75% of RDCF and F_7 = Vermicompost @ 5 t ha^{-1} + 50% of RDCF.

Conclusion

Considering the above results, it may be concluded that sunflower var. BARI Surjumukhi-2 variety consistently outyielded BARI Surjumukhi-3 in terms of plant height, leaf area, dry weight, head diameter, number of seeds head^{-1}, weight of 1000 seeds, seed yield, stover yield, harvest index, and seed oil content (40.77%). The interaction effects highlighted that BARI Surjumukhi-2 combined with vermicompost at 5 t ha^{-1} + 75% of the recommended dose of chemical fertilizers (V1F6) achieved the highest values with a head diameter (13.15 cm), number of seeds head^{-1} (242.29), weight of 1000 seeds (49.51 g), seed yield (1.31 t ha^{-1}), stover yield (5.17 t ha^{-1}), harvest index (21.02 %) and seed oil content (38.35%).

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