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Impacts of Vermicompost and Farmyard Manure as Organic Fertilizer with Biochar Amendment on Soil Quality, Growth and Yield of Sunflower

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ABSTRACT

Background: Sunflower is an economically important and the fourth most valuable oil seed crop. The study aimed to investigate organic fertilizers as an alternative method of enhancing soil quality and to determine the optimal combination of organic fertilizer treatments for sunflower growth performance and yield.

Methods: The sunflower variety BARI Surjamukhi-2 was used in this study. The treatments were applied as T1= Control; T2= Farmyard Manure @ 2 t ha^{-1}; T3= Vermicompost @2 t ha^{-1}; T4= Biochar @2 t ha^{-1}; T5= Farmyard Manure @1 t ha^{-1}+Vermicompost @ 1 t ha^{-1}; T6= Farmyard Manure @1 t ha^{-1}+Biochar @1 t ha^{-1} and T7= Vermicompost @ 1 t ha^{-1}+Biochar @1 t ha^{-1}.

Result: The data showed that application of different organic fertilizer treatments improves soil quality. Organic fertilizer addition had a positive effect on the growth traits like plant height, leaves number $plant^{-1}$, stem diameter, chlorophyll content, head diameter, fresh and dry seed number $head^{-1}$, 1,000-seed weight and seed yield. The correlation results strongly agreed that chlorophyll content, fresh seed number, head diameter $plant^{-1}$ and 1,000-seed weight could be considered as selection indices for high yield of sunflower. This demonstrates the organic fertilizer's capacity to improve sunflower growth and yield, as well as its significant potential to replace chemical fertilizers in the perspective of crop sustainability.

Key words: Biochar, Farmyard manure, Sunflower, Vermicompost.

INTRODUCTION

Sunflower (*Helianthus annuss* L.) is identified as a significant source of superior edible oil used mostly for culinary purposes. Sunflower oil is in high demand because it is cholesterol-free and high in polyunsaturated fatty acids (Pal *et al*., 2015; Ramamoorthy *et al*., 2021). Because of the continual expansion in human population, mostly sunflowers and other oilseeds currently dominate the international oilseed market. To meet the need for edible sunflower seeds, oil and byproducts, efforts to increase sunflower output must be increased (Adeleke and Babalola, 2020). More than 90% of Bangladesh's demand for finished sunflower oil is satisfied by imports, but growing sunflowers are becoming more and more popular because of a sudden increase in demand. As market demand for sunflower oil expands, Bangladesh takes the risk of producing this high-value crop, realizing its enormous future potential (Department of Agricultural Extension, 2022).

Sunflowers can grow in a variety of soil types and climatic conditions. The main problems with sunflower production in Bangladesh are the use of chemical fertilizers, irrigation facilities, lack of seed on time, the absence of a sunflower oil mill, market, hard seed coats and low yield. To increase crop productivity, utilizing chemical fertilizers has led to soil deterioration, decrease physical and chemical properties of soil, yield, microbial ecological imbalance and surface runoff. Excessive chemical fertilization, such as nitrogen fertilization of sunflower, not only endangers the environment, but can also affect seed quality by increasing plant lodging, lowering oil content and decreasing crop yield (Scheiner *et al*., 2002; Sarker *et al*., 2022).

Growers have started to use alterations such as organic fertilizers to improve the chemical structure of soils and increase output from the crop. Organic fertilizers like farmyard manure, vermicompost, biochar that come from natural sources like animal and poultry manure, plant

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waste, biogas residue and agricultural byproducts can help reduce pollution. Organic fertilizers are regarded as a crucial part of sustainable agricultural practices and can help with long-term growth, yield and quality, as well as plant health and risk reduction (Buriro *et al*., 2015). Significant attempts have recently been undertaken to boost plant growth and production using safe and natural materials. The use of farmyard manure resulted in the maximum levels of available N, P and K in the soil activity increasing organic waste decomposition and resulting in a decrease in minimal soil pH. By encouraging microorganisms, vermicompost increases soil fertility, porosity and crop productivity. Biochar has a porous structure, broad surface area and high surface charge density. It is particularly effective in restoring soil fertility, increasing nutrient retention, reducing nutrient leaching and playing an essential role in achieving agricultural environmental sustainability (Ayaz *et al*., 2021). Biochar increases water-holding capacity, electrical conductivity, cation exchange capacity allowing cations to be retained in an exchangeable and plant-available form. Numerous studies have documented application of organic fertilizers an increase in soil microbial activity, which in turn improved sunflower crop growth and yield (Alzamel *et al*., 2022). Therefore, objectives of the research work were i) to identify whether organic fertilizers may be used as an alternate method for improving soil quality and ii) to select the best combination of organic fertilizer treatments for growth performance and higher yield of sunflower.

MATERIALS AND METHODS

Research place and experimental design

The experiment was carried out at the Hajee Mohammad Danesh Science and Technology University in Dinajpur, Bangladesh (25.13°N, 88.23°E) and was designed using a randomized complete block design. Soil properties were analyzed before sowing and harvesting times at the Soil Resource Development Institute (SRDI), Dinajpur, Bangladesh by collecting from 0-50 cm soil layer. The water content of the soil was measured to determine the field capacity at two to three days after irrigation. The sunflower seed (variety BARI Surjamukhi-2) was collected from the Institute Bangladesh Agricultural Research Institute (BARI), Gazipur. The treatments were applied as T1= Control; T2= Farmyard Manure (FYM) @ 2 t ha^{-1}; T3= Vermicompost (VC) @ 2 t ha^{-1}; T4= Biochar (BC) @ 2 t ha^{-1}; T5= Farmyard Manure @ 1 t ha^{-1}+Vermicompost @1 t ha^{-1}; T6= Farmyard Manure @ 1 t ha^{-1}+Biochar (BC) @1 t ha^{-1} and T7= Vermicompost @1 t ha^{-1}+Biochar @1 t ha^{-1}. The total number of plots was 21 and the unit plot size was 10 m^2. The planting method was done in a continuous row maintained 75 cm. Distances between plant to plant, plot to plot in the same replication and replications were 30, 100 and 1.75 cm, respectively. The nutrient content of vermicompost was 12.6% organic carbon, 1.6% nitrogen, 0.7% phosphorus, 0.8% potassium, 0.5% calcium and 0.2% magnesium. The nutrient content of farmyard manure was 10.7% organic carbon, 0.5% nitrogen, 0.2% phosphorus, 0.5% potassium, 0.9% calcium and 0.2% magnesium.

Data collection

Data was recorded by observing ten plants randomly selected from each plot. The traits were plant height (cm), leaves number $plant^{-1}$, stem diameter (cm), chlorophyll content (%) which was measured by SPAD 502 Plus Chlorophyll Meter (Japan), head diameter (cm), fresh and dry seed number $head^{-1}$, 1,000-seed weight (g) and seed yield (t ha^{-1}).

Statistical analysis

The analysis of variance was used to examine differences in all experimental data, the relationship between different organic fertilizers and variety, with yield attributes of sunflower evaluated by the F-test for mean comparisons at 5% probability level using R program (version 4.2.1). Origin Pro 2022 (version-9.8.200) did weather graphs, correlation between the yield contributing traits and comparison graphs.

Climatic conditions

The main characteristic of the study area was the subtropical climate, which had low temperatures and little rainfall from December 2021 to April 2022. The month of April recorded the highest temperature (38.18°C), while the lowest temperature was recorded in December (12°C) (Fig 1a). December 2021 had the highest humidity (57%), while March 2022 had the lowest humidity (38.12%) (Fig 1b).

RESULTS AND DISCUSSION

Soil analysis

Before the application of treatments, the soil's parameters were as follows: pH was 6.8, organic matter was 0.31%, organic carbon was 0.18%, available phosphorus was 14.30%, available potassium was 14.30%, total nitrogen was 0.07%, electrical conductivity was 132.30 µS cm^{-1} and field capacity was 52.50%. The soil had the following properties at the harvesting time: pH was 6.1, organic matter was 0.34, organic carbon was 0.18%, available phosphorus was 42.90 mg kg^{-1}, exchangeable potassium was 31.60 mg kg^{-1}, electrical conductivity was 148.60 µS cm^{-1} and field capacity was 78.70%. (Table 1). According to Gunay (2014), using organic fertilizers boosted sunflower production and soil qualitative factors by enhancing the level of soil nitrogen, phosphorus and potassium. The effect of biochar in acidic soils enhances nutrient availability. This finding corroborated prior research that demonstrated enhanced nutrient content, particularly phosphate and potassium, in soil modified with a biochar-vermicompost mixture. According to Mila *et al*. (2017), a 60% depletion of field capacity is optimum for better sunflower production.

Reducing water flow may improve water savings while affecting yield production, however the yield loss from deficit irrigation is balanced by the benefits of reduced water use. Furthermore, they indicated that a 60% moisture availability deficit while utilizing as the target depth may be defined as a strategic way to preserve water while still attaining optimum water usage efficiency and they attained a maximum sunflower seed yield. The accumulation of organic fertilizers decreased the soil pH.

Analysis of variance

The result showed that the harvesting stage had the maximum plant height (92.83 cm) and the 25 DAS had the lowest effect (21.30 cm). The largest number of leaves plant^{-1} was shown the same at 90 DAS and the harvesting stage at 31.71. The lowest was 8.89 at 25 DAS. A very close inspection was found for stem diameter at 90 DAS and harvesting stage with 6.40 to 6.46 cm. At the 25 DAS, the lowest performance was 1.20 cm. The findings demonstrated that all organic fertilizer treatments, whether in combination with or without, resulted in a considerable increase in sunflower chlorophyll content. The chlorophyll content was 85.60, 79.11 and 77.50 µmol m^{-2} at 70, 50 and 90 DAS, respectively. The results in the same table show that the highest flower head diameter was observed at 90 DAS (62.44 cm) and at the harvesting stage (60.32 cm) (Table 2).

Table 1: Soil physical and chemical properties used in the growing season.

Parameters measured	Before sowing	Harvesting time
Soil textural	Sandy loam	Sandy loam
Organic matter (%)	0.31	0.34
Organic carbon (%)	0.18	0.19
Total N (%)	0.07	0.072
Available P (mg kg^{-1})	14.30	42.90
Exchangeable K (mg kg^{-1})	28.05	31.60
Field capacity (%)	52.50	78.70
EC (µS cm^{-1})	132.30	148.60
pH	6.80	6.10
Soil moisture (%)	12.50	13.55
Water holding capacity (%)	27.78	38.50

Pearson's correlation

Correlation results indicated a strong correlation among the traits with different organic fertilizer treatments (Fig 2). Plant height showed a positive correlation with stem diameter (0.81), leaves number plant^{-1} (0.86), fresh seed head^{-1} (0.88), fresh head diameter plant^{-1} (0.88), 1,000-seed weight (0.87), chlorophyll content (0.78) and seed yield (0.86). Anandhan *et al*. (2010) showed similar results. Stem diameter showed a highly positive correlation with chlorophyll content (0.95) and fresh head diameter plant^{-1} (0.90). However, leaves number plant^{-1} had highly positive correlation with fresh head diameter plant^{-1} (0.90) and chlorophyll content (0.81). Fresh seed head^{-1} showed highly positive correlation with 1,000-seed weight and seed yield (0.90). Furthermore, dry seed head^{-1} showed a positive correlation with seed yield (0.88). Fresh head diameter showed strong correlation with chlorophyll content (0.92). 1,000-seed weight showed a positive correlation with seed yield (0.97). Therefore, the correlation results strongly agreed that chlorophyll content, fresh seed number, head diameter plant^{-1} and 1,000-seed weight could be considered as selection indices for a high yield of sunflower.

Plant height

Organic fertilizer application has led to increased vegetative growth and eventually increased plant height. Among organic fertilizer treatments, the T7 resulted in increased plant height than the other treatments. The longest plant height measured during harvesting time was 181.0 cm for T7 and the shortest was 14.7 cm for T1. At 70 DAS, 50 DAS

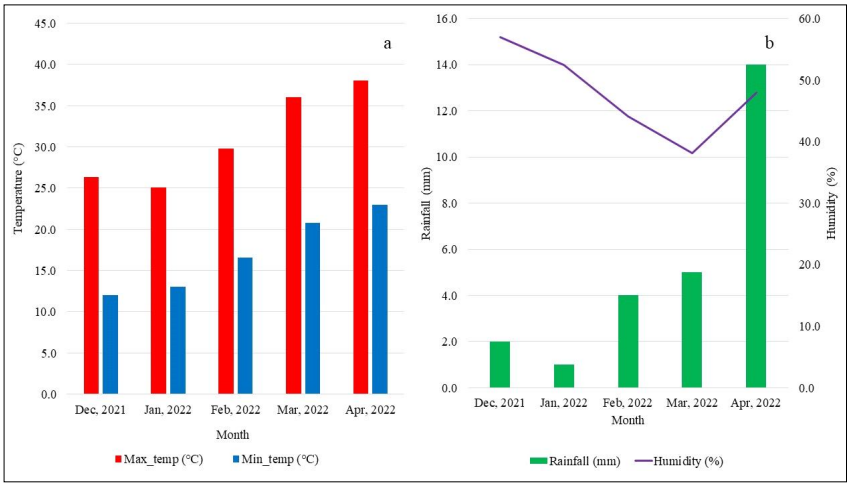
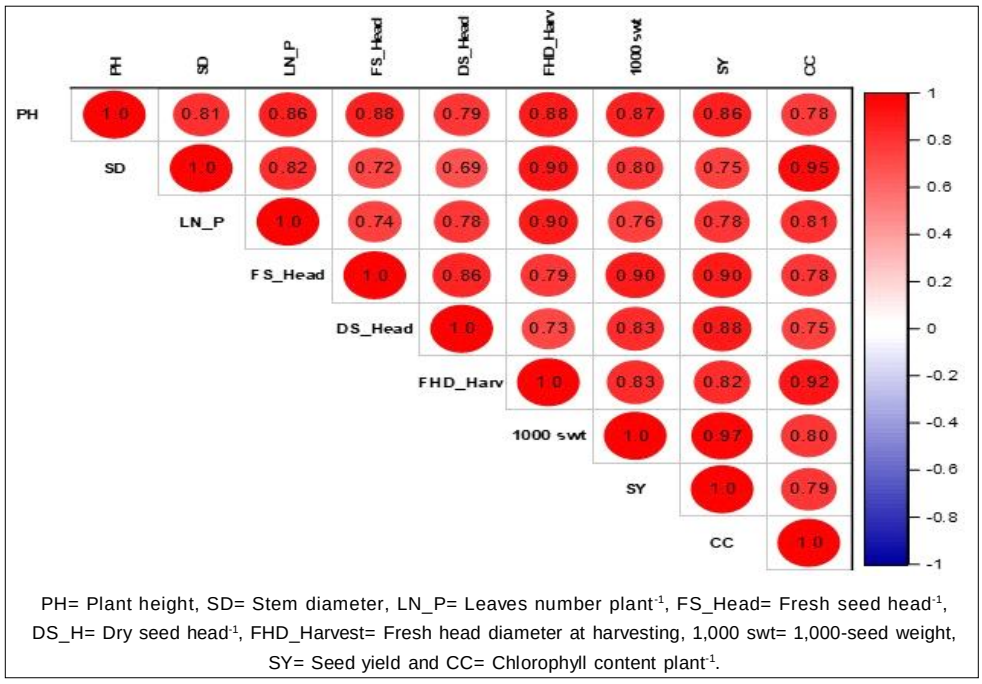


Fig 1: Maximum and minimum temperature (a) and average relative humidity and rainfall (b) during the experimental year.

Table 2: Analysis of variance for yield contributing traits of sunflower.

Parameters	Days	MS treatment	MS error	CV	F-test
Plant height (cm)	25 DAS	21.30	1.18	12.17	**
	50 DAS	55.52	29.48	13.61	**
	70 DAS	85.97	12.81	6.70	**
	90 DAS	88.94	7.95	4.86	**
	Harvesting	92.83	7.52	4.63	**
Leaves number plant^{-1} (no.)	25 DAS	8.89	0.52	10.86	**
	50 DAS	19.05	3.91	14.07	**
	70 DAS	26.76	2.00	9.34	**
	90 DAS	31.71	7.90	14.83	**
	Harvesting	31.71	7.90	14.83	**
Stem diameter (cm)	25 DAS	1.20	0.02	12.73	**
	50 DAS	4.40	0.60	38.36	**
	70 DAS	4.83	0.23	15.28	**
	90 DAS	6.40	0.33	14.14	**
	Harvesting	6.46	0.30	13.28	**
Chlorophyll content (µmol m^{-2})	25 DAS	48.12	0.67	2.39	**
	50 DAS	79.11	7.64	6.57	**
	70 DAS	85.60	134.10	18.20	**
	90 DAS	77.50	158.70	23.54	**
Flower head diameter (cm)	70 DAS	55.12	6.49	15.60	**
	90 DAS	62.44	3.86	8.51	**
	Harvesting	60.32	3.87	8.25	**
1,000-seed weight (g)	Harvesting	215.43	1.86	4.90	**
Number of seed head^{-1} (no.)	Fresh	714.00	205.00	2.68	**
	Dry	681.30	29.10	5.24	**
Number of seeds plant^{-1} (no.)	Fresh	105,071.00	5,386.00	15.02	**
	Dry	4,005.00	60.00	8.55	**

** Significant at p<0.01



PH= Plant height, SD= Stem diameter, LN_P= Leaves number plant^{-1}, FS_Head= Fresh seed head^{-1}, DS_H= Dry seed head^{-1}, FHD_Harvest= Fresh head diameter at harvesting, 1,000 swt= 1,000-seed weight, SY= Seed yield and CC= Chlorophyll content plant^{-1}.

Fig 2: Plot of Pearson's correlation analysis among the yield contributing traits of sunflower.

and 25 DAS, the T7 resulted in the longest plant height (153.0 cm, 106.33 cm and 30.17 cm). T1 produced the shortest plant height (98.7 cm, 93.33 cm and 30.17cm) (Fig 3a). The result is comparable to that of applying organic fertilizer which no discernible impact on plant height has been noted (Khan *et al*., 2016).

Leaves number per plant

At harvesting, maximum leaves number plant^{-1} was recorded at T7 (48.7 number), at 90 DAS the second highest leaves number was recorded from T7 (45.0 number) and the lowest leaves number plant^{-1} obtained from T1 (26.3 number and 26.2 number). While at 25 DAS, at the earlier or vegetative stage the highest leaves number plant^{-1}, was recorded from T5, T6 and T7 (19.7 number) and the lowest leaves number plant^{-1} was obtained from T1 (8.7), at control treatment (Fig 3b). Both fertilizers were equally effective at increasing total leaf number per plant and total yield per plant, as stated by Rivelli and Libutti (2022). The increase in required days for sunflower maturity may have resulted in increased synthesis of amino acids, protein and other growth promoting substances, which appear to have enhanced meristematic activity, increased cell division and increased leaves number plant^{-1}.

Stem diameter

During harvesting and 90 DAS, T6 and T7 had the largest stem diameter (12.7 cm) and T1 had the smallest stem diameter (0.72 cm). At 70 DAS, the maximum stem diameter was obtained from T5 and T7 (9.3 cm), while the minimum stem diameter was obtained from T1 (2.5 cm) (Fig 3c). Acharya *et al*. (2022) found that the highest value of stem diameter was measured after the application of compost combined with biochar organic fertilizer.

Chlorophyll content

Chlorophyll content was an important parameter in the production of all crops. It was found to be statistically significant at 25, 50, 70 and 90 DAS. At 70 DAS, the highest chlorophyll content was recorded from T7 (193.67 µmol m^{-2}) (Fig 3d). Kumari (2017) reported that chlorophyll content was found to be more related to chloroplast membrane organization, new leaf formation, individual leaf expansion and the process of mobilization of various nitrogen pools in younger leaves than in older leaves. For this reason, at 90 DAS, the highest result was recorded from T5 (164.67 µmol m^{-2}) and T7 (165.67 µmol m^{-2}) which was comparatively lower than 70 DAS.

Flower head diameter

The application of different organic fertilizer treatments had a significant impact on the flower head diameter in different growth stages of sunflower. The result showed that at the harvesting stage T7 had the highest flower head diameter (30 cm) with the nearest result observed from T6 (29 cm). The lowest performance was shown by T1 at all stages (Fig 4a). Balalic *et al*. (2016) reported that organic fertilizer management had a significant influence on flower head

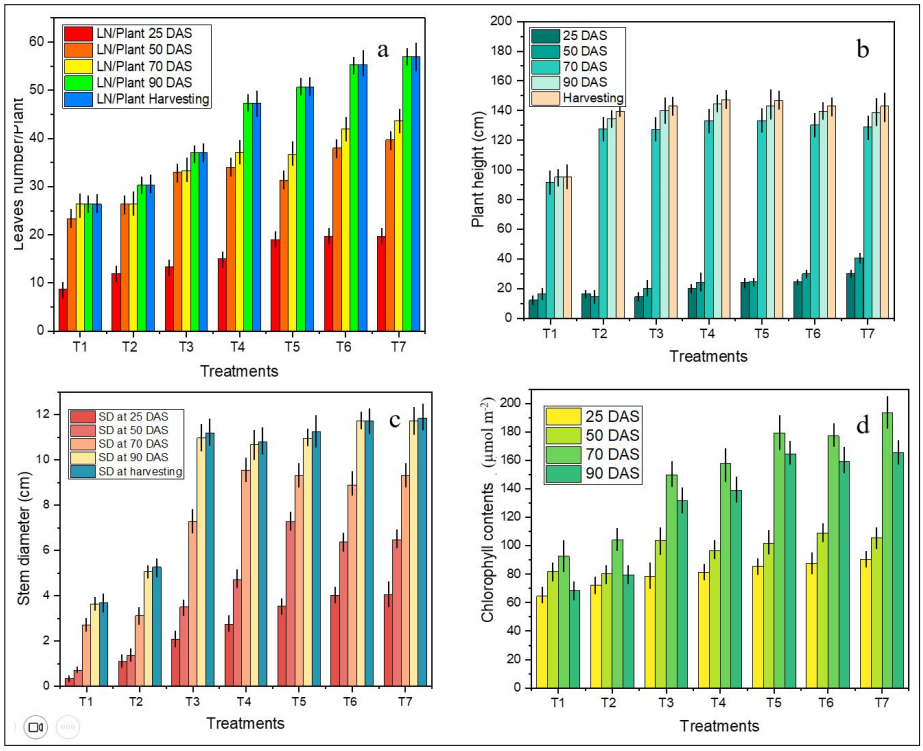


Fig 3: The effect of different organic fertilizer treatments on plant height (a), leaves number plant^{-1} (b), stem diameter (c) and chlorophyll content (d) of sunflower.

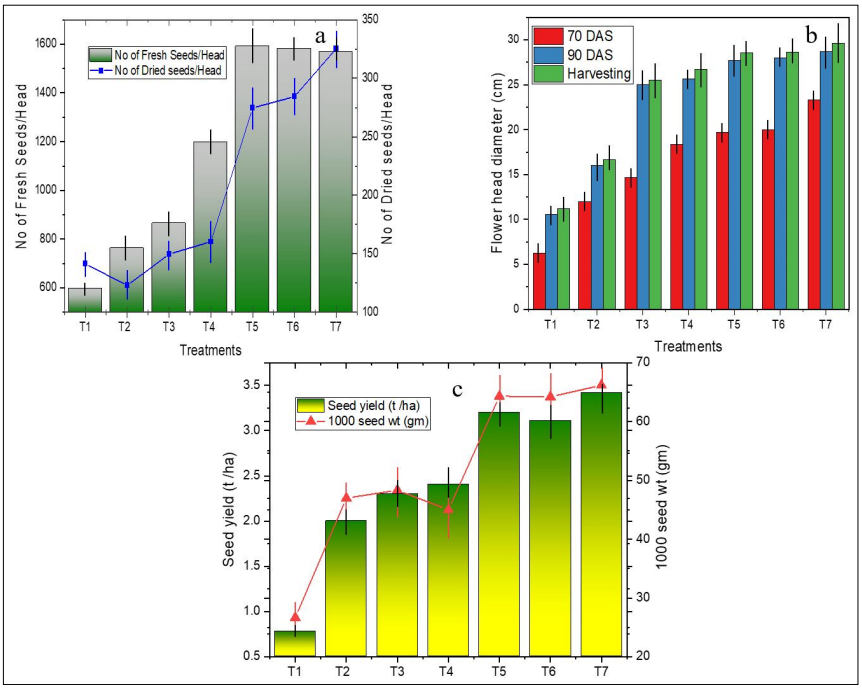


Fig 4: The effect of different organic fertilizer treatments on flower head diameter (a), fresh and dried number of seeds head^{-1} (b) and 1,000-seed weight and seed yield (c) of sunflower.

diameter in the flowering and physiological maturity stages in sunflower by the use of integrated nutritional levels.

Fresh and dry seed number per head

The fresh and dried seed number head^{-1} indicated both responded significantly to the application of various doses of organic fertilizer treatments. The data gathered during harvesting revealed that T5 (1,457) had the highest fresh seed number head^{-1}, which is nearly comparable to T6 (1,447) (Fig 4b). More specifically the rich content of these the co-application of FYM and VC likely accounted for this result also reported by Zhao *et al*. 2017. While T1 had the least number of fresh seed head^{-1} (441). Additionally, T7 recorded the highest number of dry seed heads^{-1} during harvest time (293).

1,000-seed weight

The plot treated with T5 produced the highest 1,000-seed weight (85.67 g), which is statistically comparable to T6 (85.40 g) and T7 (85.67 g), respectively. The lowest 1,000-grain weight (26.33 g) was obtained with T1 (Fig 4c). A higher chlorophyll content increases the photosynthetic rate and the movement of photosynthates from the source to the sink may be the reason for the higher seed weight to the grains. The balanced supply of vital nutrients from organic sources may be the cause of the increased photosynthetic rate and partitioning. Subhan *et al*. (2017) recorded the highest 1,000-seed weight by the application of FYM along with chemical fertilizers.

Seed yield

Fertilizer management had a significant effect on the seed yield of sunflower. The highest seed yield was obtained from T7 (3.42 t ha^{-1}) and the lowest seed yield was obtained from T1 (0.78 t ha^{-1}) (Fig 4c). Improvement of yield components such as flower head diameter and number of seeds head^{-1} ultimately increased the seed yield of sunflower. The result was strongly supported by Rasool *et al*. (2013) who reported that grain yield was significantly increased by the application of organic matter along with fertilizers. Langeroodi *et al*. (2021) reported that sunflower seed yield ranged from 1.78 to 4.95 t ha^{-1} and was increased by the biochar application. The application of biochar and vermicompost combination has a positive influence on the growth characteristics of sunflowers and will be helpful in attaining the maximum quality, healthy seed and yield.

CONCLUSION

The current study indicated that co-applying diverse types of organic fertilizer sources had an overall positive effect on the soil parameters. Plant height, leaves number plant^{-1}, stem diameter, chlorophyll content, head diameter, fresh and dried seed number head^{-1}, 1,000-seed weight and seed yield were all positively improved by the addition of organic fertilizer. The correlation results strongly agreed that chlorophyll content, fresh seed number, head diameter plant^{-1} and 1,000-seed weight could be considered as selection indices for high yield. This result indicates the organic fertilizer's efficacy in encouraging sunflower growth, as well as its huge potential to substitute inorganic fertilizer in the context of sustainable crop production. Therefore, combining vermicompost with biochar is a preferable option for assuring the sustainability of sunflower production.

Conflict of interest

The authors declare that we have no conflict of interest regarding the publication of this paper.

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