INFLUENCE OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF SUNFLOWER (*Helianthus annuus* L.)

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CERTIFICATE

*This is to certify that the thesis entitled, "**INFLUENCE OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF SUNFLOWER (Helianthus annuus L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **ANIKA TABASSUM,** Registration no. **19-10202** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date:

Place: Dhaka, Bangladesh

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Dedicated to My

Nurturers,

Especially My

Parents

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The Author

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to March 2021 in Rabi season, to study the influence of organic and inorganic fertilizers on growth, yield attributes and yield of sunflower. The experiment consisted of two factors, and followed split plot design with three replications. Factor A: Organic manure (3) viz: OM_0: Control (without manure), OM_1: Cowdung 10 t ha^{-1}, OM_2: Vermicompost 5 t ha^{-1} and Factor B: Inorganic fertilizer (4) viz: F_0 = Control (without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF. Experimental result revealed that different organic and inorganic fertilizers significantly influenced the growth, yield and yield attributing parameters of sunflower. In case of different organic fertilizers, cowdung 10 t ha^{-1} (OM_1) treatment gave the highest plant height, dry weight per plant, SPAD value at different days after sowing, head diameter (12.35 cm), seeds $head^{-1}$ (401.67), 1000-seed weight (63.87 g), seed yield (2.13 t ha^{-1}), biological yield (7.15 t ha^{-1}), stover yield (5.02 t ha^{-1}) and harvest index (28.39 %). Whereas the lowest seed yield (1.56 t ha^{-1}) was recorded from OM_0 as control. However, in case of different levels of inorganic fertilizers, the highest seed yield (2.19 t ha^{-1}) was recorded in RDF (F_3) treatment which was due to enhanced yield attributes like head diameter (12.63 cm), seeds $head^{-1}$ (422.78) and 1000-seed weight (64.54 g) but F_2 (75% of RDF) treatment also showed statistically similar result with F_3 treatment. In case of combination, cow dung 10 t ha^{-1} along with RDF (OM_1F_3) performed best in respect of growth and yield attributes and yield parameters, like head diameter (13.71 cm), seeds $head^{-1}$ (453.33) and 1000-seed weight (66.84 g), leading to the maximum seed yield (2.19 t ha^{-1}), biological yield (8.18 t ha^{-1}), stover yield (5.71 t ha^{-1}) and harvest index (30.2 %) than compared to other treatment combinations but OM_1F_2 (cowdung 10 t ha^{-1} along with 75% of RDF) was statistically at par with OM_1F_3 in respect of yield and yield attributes parameter. Therefore, it may be suggested that application of cowdung 10 t ha^{-1} along with 75% RDF (OM_1F_2) would help to plant growth and increase its ability to enhanced better yield of sunflower.

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LIST OF ABBREVIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CV%	=	Percentage of coefficient of variance
cm	=	Centimeter
DAS	=	Days after sowing
dS/m	=	deciSiemens per meter
et al.	=	and others
kg/ha	=	Kilogram/hectare
g	=	gram
HI	=	Harvest Index
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
N	=	Nitrogen
No.	=	Number
NS	=	Not significant
NPK	=	Nitrogen, Phosphorus and Potassium
pH	=	Hydrogen ion conc.
SAU	=	Sher-e-Bangla Agricultural University
SPD	=	Split plot design
SRDI	=	Soil Resources and Development Institute
TSP	=	Triple Super Phosphate
%	=	Percent

CHAPTER I

INTRODUCTION

Acute shortage of edible oil has been prevailing throughout the last many decades in Bangladesh (Khatun *et al*., 2016). According to Hossain (2014), Bangladesh produces 0.358 million tons of edible oil against a demand of 1.6 million tons. The remainder of 1.242 million tons is met up through foreign import.

Sunflower (*Helianthus annuus* L.) is an oilseed crop (2n=34) belongs to family Asteraceae, tribe Heliantheae, which contains 20 genera (Deshmukh *et al*., 2016). It is native to temperate regions of North America, although was domesticated in Russia as an oil crop in the early eighteenth century. Now it is the world's 4th largest source of oilseed crop (Masvodza *et al*., 2014) after Soybean, palm and rapeseed. During 2015-16, the total world production of sunflower oil was 1585000 tons (FAS, USDA, 2016) which accounts for about 14% of the total world oil production. Besides, sunflower also contributed a total of 7% oil cake worldwide (Masvodza *et al*., 2014). Major sunflower growing countries in the world are Russia, CIS, Argentina, Europe, China, USA and India (Arshad *et al*., 2010). Sunflower seeds contain about 50% of fat and 20% of protein. Sunflower oil is considered a premium oil as it contains high percentage of unsaturated fatty acids, light color, low quantity of linolenic acid, blend flavor and high smoke point. Oleic and linoleic acid are primary fatty acids (approximately 90% unsaturated fatty acids) in sunflower oil, however among others are palmitic and stearic saturated fatty acids (Arshad *et al*., 2007). Sunflower seeds are strong source of vitamins E, B_1, B6, folate, and niacin. Additionally, the seeds are a good source of Cu, Mn, Se, P, and Mg. Sunflower contains phytosterols which helps to reduce cholesterol in serum through cholesterol excretion to alter cholesterol synthesis (Ngongoni *et al*., 2007)

Sunflower is a thermos-neutral crop, therefore, can be grown throughout Bangladesh both in rabi and kharif season. It is drought tolerant (Arshad *et al*., 2019), can be cultivated in limited water area, and even in Barind tract as it requires less irrigation than other oilseed crops. It is a short duration crop (Arshad *et al*., 2019) which can be grown in between aman and boro rice. It can be grown in wide ranges of soil types (from sand to clay) along with a wide range of soil pH (5.7- 8). Sunflower can endure approximately 2-12 dS/m threshold of salinity. In Bangladesh Sunflower is a non-

conventional oilseed crop which started to cultivate since 1975, but on a small scale (Habib *et al*., 2007). The maximum area (4000 ha) and production (6000 tons) of sunflower was reported in year 2014-15, thereafter it has been declining gradually (Krishi Diary, 2019).

Fertilizers, which are important for oilseed plants, make important contributions to the entire stage of cultivation, from sowing seeds to ripening and harvesting. Sunflower absorbs more nutrients from the soil than many cultivated plants, and this enlarges the importance of fertilization.

Cowdung and vermicompost fertilizers contain different types of microorganisms, algae extracts and enzymes, are more effective in plant growth and development (Atiyeh *et al*., 2000). Cowdung can improve soil fertility, increase water-holding capacity, decrease soil erosion, improves amount of oxygen, and promotes beneficial organisms and productivity (Cassman *et al*., 1995; Hamza and Abd-Elhady, 2010). Vermicompost contain plant growth regulators and other plant growth influencing materials including humates, produced by microorganism (Tomati *et al*., 1988; Grappelli *et al*., 1987; Atiyeh *et al*., 2002).

Nitrogen affects the seed quality by increasing proteins and decreasing oil concentration (Gudade *et al*., 2009). Sulphur helps in the synthesis of cystein, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, especially by its effect on the protolytic enzymes (Najar *et al*., 2011). Application of nitrogenous, phosphatic and potash fertilizer above or below the optimum level adversely affects the growth and yield.). Various combinations of NPK had profound impact on achene yield of sunflower (Malik *et al*., 2006). Nitrogen fertilizer application enhances cost of production more than any other nutrient (Aslam *et al*., 2011), however, Nitrogen is considered essential element for plant kingdom and growth processes in crops (Laegreid, 1999) and has fundamental importance for plants but its availability in the soil is in low concentration (Tisdale *et al*., 2003). Boron has a synergistic effect on nitrogen uptake, which is straightly connected with amino acids, RNA, and protein synthesis thereby increasing the relative growth rate and absolute growth rate. Although numerous studies highlighted the positive effects of boron application on growth, yield and oil content of sunflower, limited information is available on the influence of boron nutrient in sunflower crop cultivated in acid laterite soils (Jagadala *et al*., 2020).

Nitrogen fertilizer enhances crop growth indices, yield and quality attributes. (Abdalla *et al.*, 2013). Phosphorous ranks 2nd to nitrogen in its role for crop growth and development. Plant community desire optimum phosphorus from its very early stage to sustain efficient production of crops (Grant *et al*., 2005). Phosphorous promotes root development, seed size and final grain yield of hybrid sunflower (Arif *et al.*, 2003). Potassium significance is not inferior to any other nutrient. Potassium uptake is more than or almost equal to nitrogen. Potassium is regarded as chief element in improvising the crop quality as well as drought resistance (Reddy, 2004). Significant jump in agronomic parameters specifically yield components of sunflower had shown encouraging results by incorporating potassium in fertilizer application program (Munir *et al*., 2007; Iqbal *et al*., 2008).

The use of organic or inorganic fertilizers alone does not increase the plant productivity to the expected level. It was reported that a crucial interaction existed between the implementation of organic manures and the efficiency of inorganic fertilizers (Gorttappeh *et al*., 2000; El-Ghamry *et al*., 2009) and they enhanced the benefits of most nutrients (nitrogen, phosphorus, and sulfur, etc.) (Waclawowicz *et al*., 2006). Hussain *et al*. (2010) found a higher plant height and dry matter yield when inorganic fertilizers were used alone and in combination with organic manures. The use of vermicompost alone or in combination with other organic or mineral fertilizers was found to be effective in increasing the growth and yield of various plants (Singh *et al*., 2011). On the other hand, the highest grain yield (1878 - 2160 kg ha^{-1}) and 1000-grains weight (56.67 g) were reported to be obtained by using vermicompost in combination with chemical fertilizers such as nitrogen (Sharma *et al*., 2008; Soleymani *et al*., 2016). The highest plant height, stem diameter, head diameter, grain yield, and oil content were obtained in sunflower by the combinations of organic and inorganic fertilizers (Buriro *et al*., 2015). Inorganic fertilizers interacted with organic manures result in reduction of soil nitrate contents (Yang *et al*., 2005), enhance of the cation-exchange capacity and soil organic matter, improvement of soil properties and increase of crop yield (Mohammad, 1999). Therefore, the integrated fertilizers are a useful means to enhance crops yields and increase the soil fertility (Mahapatra and Sharma, 1989).

Fertilizers can progress soil structures and fertility by motivating biological activity and increasing phosphorus solubility in soil. Despite their increased use, a sufficient

yield increase cannot be achieved. Keeping in view of the above facts, an experiment was planned and under taken on “Influence of organic and inorganic fertilizers on growth, yield attributes and yield of sunflower, with following objectives:

i. To find out the effect of organic manure on the performance of sunflower,
ii. To evaluate the impact of different levels of chemical fertilizers on the performance of sunflower, and
iii. To investigate the interaction effect of organic and inorganic fertilizers on growth and yield of sunflower.

CHAPTER II

REVIEW OF LITERATURE

Organic and inorganic fertilizers are the most important nutrient elements for maximizing the yield of sunflower. The proper fertilizer management essentially impacts it's growth and yield performance. Experimental evidences showed that there is a profound influence of organic and inorganic fertilizers on this crop. The fertilizer requirements, however, varies with the soil and cultural conditions. Research works have been done in various parts of the world including Bangladesh is not adequate and conclusive. Some of the important and informative works conducted home and abroad in this aspect, have been furnished in this chapter.

Shoghi *et al*. (2018) demonstrated that the combined application of fertilizers crucially increased the leaf area index, plant height, grain production, biomass, oil yield, and protein content in comparison with organic or chemical fertilizers. The maximum and minimum oil contents were gained by applying 100% farmyard manure and 50% FM + 50% chemical respectively; however, opposite results were observed for protein content. The highest contents of linoleic acid (52.6%) and oleic acid (39.8%) were reported in (50% FM+50% chemical) and (100% farmyard manure (FM) 48 t ha^{-1}) treatments.

Malligawad *et al.* (2004) conveyed that 180 N ha^{-1} proved useful dose for obtaining bumper crop yield of sunflower.

Akbari *et al*. (2011) showed that the height, leaf area index, biological yield, 1000-seed weight, number of seeds, head diameter, harvest index and qualitative properties (except for the oil content) were higher in the 50% chemical and 50% organic, 75% chemical and 25% organic and 25% chemical and 75% organic integrated nutritional levels compared to the completely organic and chemical levels.

Namvar *et al*. (2011) observed that the highest plant height, stem and head diameter, number of grains per head, 1000-grains weight, grain yield, oil yield and biological yield were gained from the maximum level of nitrogen fertilizer (200 kg N ha^{-1}) and biofertilizer inoculation.

Elankavi (2017) evaluated the results that combined application of RDF + vermicompost @ 5 t ha^{-1} + foliar application of MnSO4 0.5 per cent on 40 and 60 DAS significant increase in growth attributes (plant height, LAI and DMP), yield attributes (head diameter, total numbers of seeds, number of filled seeds and 100 seed weight) and yield of sunflower, and it was followed by RDF + pressmud @ 10 t ha^{-1} + foliar application of MnSO4 @ 0.5 percent on 40 and 60 DAS. The minimum growth and yield parameters and yield were recorded with control.

Ghosh *et al*. (2013) found that nutrients from vermicompost along with inorganic fertilizer and micro nutrient reflected on increased growth attributes of sunflower.

Rasool *et al,* (2013) observed that the plant height, leaf area index and dry matter production recorded significant and consistent increase with increase in nitrogen rates from 40 to 120 kg ha^{-1}. Nitrogen rates of 80 and 120 kg ha^{-1} at par with one another, significantly enhanced the total number of achenes/capitulum, number of filled achenes/capitulum and 1000-seed weight over 40 kg N ha^{-1}. The luxurious seed yield (2.5 t ha^{-1}) was recorded with 120 kg N ha^{-1} which remained at par with 80 kg N ha^{-1} (2.4 t ha^{-1}) and net returns (Rs. 53793), B:C (2.1) ratio was maximum with 120 kg N/ha. Application of 60 kg S ha^{-1} recorded maximum seed yield (2.42 t ha^{-1}) and net returns (Rs. 49115). Same dose of treatment also recorded maximum oil content and oil yield. Application of FYM @ 10 and 20 t ha^{-1} improved seed yield up to the tune of 9 and 15% over no application, respectively. With net returns of Rs. 49093 FYM @ 10 t ha^{-1} proved more profitable. Available nitrogen recorded was highest with treatment combination 120 kg N+60 kg S+20 t ha^{-1} FYM and lowest with 40 kg N+30 kg S+0 t ha^{-1}FYM. Similar trend was remarked for available sulphur.

Javanmard *et al*. (2016) evaluated the effect of different levels of chemical and organic fertilizers on seed yield, its components and oil content of sunflower. They showed that the highest chlorophyll index belonged to %50 nitrogen + 50% phosphorus plus poultry manure and nitrogen fertilizer plus poultry manure treatment combinations respectively.

El-Sayed *et al*. (2022) conducted a field experiment to estimate the effect of organic (Poultry Manure) and inorganic fertilizers (Potassium Nitrate) on sunflower growth parameters under water stress conditions. The soil application of Poultry manure (0, 2, 4, 6 ton fed^{-1}) assumed the main plots and potassium nitrate treatments applied as a

foliar spray at the rates (0, 1, 2 and 3%) randomly distributed in the sub-plots. It was reported that the enhancement in poultry manure rates was accompanied by significant accretion in chlorophyll content, relative water content and total leaf Area. Data indicated that the maximum values of the proline content were registered for the control treatment and the minimum values recorded with the application of 6-ton poultry manure 6 ton fed^{-1} combined with 3.0 % KNO_3 foliar spray under sufficient and deficit irrigation treatments. Results showed that enhancing poultry manure rates was linked with significant enhancement of sunflower plant height, head weight, head diameter, 100 seed weight and grain yield of sunflower. Results indicated that the highest values of growth and yield parameters of sunflower were attained by application of 6.0 ton fed^{-1} poultry manure with a foliar spray KNO_3 at a rate of 3.0 % under water stress condition.

Thakur *et al*. (2018) evaluated that combined application of RDF + humic acid granules @ 12.5 kg ha^{-1} (basal) significantly influenced stem girth, SPAD chlorophyll meter readings, head diameter and thousand seed. Central unfilled diameter was significantly impacted by different treatments. Application of RDF alone recorded maximum central unfilled diameter (2.0 cm). Lowest central unfilled diameter was recorded with RDF + soil application of 12.5 kg ha^{-1} humic acid granules.

Byrareddy *et al*. (2008) reported that the increase in growth attributes might be due to higher availability of both native and applied nutrients in treatment along with better source and sink relationship in the crop which had contributed to better dry matter accumulation. The application of organic manure had a significant result on sunflower grain yield, dry matter, head dry matter, plant height and stem girth throughout all growing stages in the second cropping season with poultry manure generating the best values.

Munir *et al*. (2007) conducted an experiment to find out the yield and quality optimization through integrated crop manuring and nitrogen application on spring sunflower. They reported that fertilizer application at 50-75-50 NPK kg ha^{-1} along with poultry manure at 8 t ha^{-1} seemed to be most acceptable and satisfactory for bringing a good quality of sunflower. The inorganic fertilizers should be applied with organic fertilizers to reach the maximum yield of the crop by accreting the fertilizer use efficiency of applied inorganic fertilizers.

Esmaeilian *et al*. (2012) observed that when manure alone or in amalgamation with chemical fertilizer were applied, the seed yield was highest than in control. Protein and oil percentage were higher in sheep manure and 50 % cattle manure + 50 % chemical fertilizer. All fertilization methods increased nutrient concentration of sunflower in general.

Ahmad *et al*. (2009) conducted a field experiment to perform with an objective to evaluate the effect of organic fertilizers on various parameters of vegetative and reproductive growth of sunflower. They observed that usage of only biogas slurry or vermicompost increased the vegetative and reproductive yield of sunflower but the highest yield was found in combined treatment of the both.

Dambale *et al*. (2018) conducted a field experiment to indicate that 100 % RDF + FYM @ 5 t ha^{-1} recorded significantly superior growth and yield attributes.

Javanmard *et al*. (2016) evaluated that applications of 75 kg N ha^{-1}+ 50 kg P ha^{-1} and %50 poultry manure + %50 animal manure treatment combination, resulted in grain yield increase by %42.02 as compared to the application of 75 kg N ha^{-1} + 50 kg P ha^{-1}.

Akbari *et al*. (2011) conducted an experiment to find out the results which demonstrated that both grain and biological yield made a better result during the combination of nitrogen fertilizer and farmyard manure than using either method alone. Maximum grain and biological yields of 2823.3 kg ha^{-1} and 9917.9 kg ha^{-1} were gained with the 50 % farm yard manure and 50 % N treatment. The results expressed that biofertilizer developed plant productivity and quality in sunflower seed

Dayal and Agarwal (1998) found that sunflower hybrid gave a higher yield from a combination of organic manures with chemical fertilizer.

Khan *et al.* (2001) showed organic manure gives maximum growth and yield considering all the growth parameters. When the outcome of organic manure was compared, it was evident that poultry manure generated the maximum yield. The combined application of poultry manure and sulfur on growth, yield, and oil contents of sunflower demonstrated a more significant result than application alone.

Elankavi (2017) found the results indicating that combined application of RDF + vermicompost @ 5 t ha^{-1} + foliar application of $MnSO_4$ 0.5 per cent on 40 and 60 DAS significantly enhancement in growth attributes (plant height, LAI and DMP),

yield attributes (Capitulum diameter, total numbers of seeds capitulum^{-1}, number of filled seeds capitulum^{-1} and 100 seeds weight) and yield of sunflower, and it was followed by RDF + pressmud @ 10 t ha^{-1} + foliar application of $MnSO_4$ @ 0.5 percent on 40 and 60 DAS. The least growth and yield parameters and yield were observed with control.

Krishnaprabu (2015) reported the results showing that application of recommended dose of fertilizer along with pressmud @ 5 t ha^{-1} and combine with foliar application of MnSO4 @ 0.5 % on 40 and 60 DAS recorded the higher seed yield of sunflower compared with other treatments.

Abumere *et al*. (2019) found that performance of sunflower was superior on the field fertilized with 10 t ha^{-1} chicken manure which was comparable to 90 kg N ha^{-1} NPK fertilizer. Sunflower seed yield and oil quality were superior in plots supplied with 10 t ha^{-1} chicken manure which was comparable to 60 kg N ha^{-1} NPK. Growth, yield, dry matter, and proximate content were minimum in the unfertilized plots. Biological yield and harvest index were increased by %22.9 and %15.98 respectively, as compared to control and application of %50 poultry manure + %50 animal manure.

Javanmard *et al*. (2016) evaluated that Maximum kernel number per head was produced by interaction effect of chemical nitrogen fertilizer (150 kg N ha^{-1}) animal manure (40 t ha^{-1}).

Thakur *et al.* (2013) evaluated that combined application of RDF + humic acid granules @ 12.5 kg ha^{-1}(as basal) significantly influenced the growth parameters, yield attributes, seed and stalk yield of sunflower. Application of RDF + humic acid granules @ 12.5 kg ha^{-1} (as basal) registered significantly taller plants (183.30 cm) over RDF alone and combined application of RDF + FYM @ 5 t ha^{-1} and total dry matter accumulation (170.50 g plant^{-1}) was also significantly higher with the same treatment over RDF + foliar spray of fulvic acid @ 0.5 and 1.0 % at capitulum initiation and flowering stage, RDF alone and combined application of RDF + FYM @ 5 t ha^{-1}. Humic acid with its auxin activity, induced harmonal effect on respiratory catalytic activity, cell permeability and increased nutrient uptake might have contributed to greater plant height and dry matter accumulation.

Ramesh (2017) found that application of 75% recommended dose nitrogen (RDN) + pressmud vermicompost @ 2.5 t ha^{-1} significantly recorded the higher plant height

(169.80 cm), leaf area index (4.80) seed yield (1825.77 kg ha^{-1}) oil content (40.47%) and oil yield (738.89 kg ha^{-1}). Recommended dose Nitrogen (50 kg N) alone gave lower seed yield, oil content and oil yield among the treatment combinations. However, it was significantly maximum than control (no fertilizer and no organic manure). The next in order of ranking was 75% RDN + sewage sludge vermicompost @ 2.5 t ha^{-1}. The benefit cost ratio (2.99) was also found to be higher with 75% RDN + pressmud vermicompost @ 2.5 t ha^{-1}.

Kovacik *et al*. (2010) reported that application of fermented manure resulted in statistically significant greater stem thickness, higher leaf chlorophyll content, leaf number, composites and harvest yield of seeds. The plants appeared healthy. Increasing the doses of fermented manure resulted in higher harvest yield of achenes and fat content in them. Out of the tested doses of 4, 6 and 8 t ha^{-1} of fermented manure the maximum achene yield has been achieved at the dose of 8 t ha^{-1} but it was inferior than the yield of the treatments fertilized by NPK fertilizers.

Elankavi (2017) indicated that considerable increase in yield attributes (number of $seed^{-1}$ capitulum, number of filled $grains^{-1}$ capitulum), seed yield, organic carbon, microbial population and NPK availability at the end of the cropping season with the combined application of 100 % RDF along with vermicompost @ 2.5 t ha^{-1}.

Badrul and Intikhab (2013) found that application of N at 80 and 120 kg ha^{-1} at par, significantly increased periodic growth parameters and yield over 40 kg N ha^{-1}. S at 60 kg ha^{-1} showed yield advantage over 30 kg S ha^{-1}. Seed yield with 10 and 20 t FYM ha^{-1} was significantly maximum over the control. Availability of N was highest with treatment combination of 120 kg N + 60 kg S + 20 t ha^{-1} FYM. Similarity was observed for available S.

Sharma *et al*. (2008) reported that among all the treatments, vermicompost (VC) + Fert at 25+25 kg N ha^{-1} recorded the highest grain yields of 1878 and 2160 kg ha^{-1} during both kharif and rabi seasons, respectively, which were 43.9 and 85.1% higher than their respective control plots. Apparent N recovery varied from as little as 38.30% (FYM at 50 kg N ha^{-1}) to 62.16 (25 kg N ha^{-1}) during kharif and 49.65 (75 kg ha^{-1}) to 83.28% (VC+Fert at 25+25 kg N ha^{-1}) during rabi season.

Rasool *et al*. (2013) recorded that application of 120 kg N ha^{-1} significantly increased all the yield components viz., plant height, leaf area index, dry matter production,

capitulum diameter, achenes capitulum^{-1} and 1000-seed weight. Pooled yield increased by 26 % with 120 kg N but it was statistically at par with 80 kg N ha^{-1}. With increased N dose, the oil content consistently reduced but the oil yield elevated during both years. Sulphur application at the rate of 60 kg ha^{-1} significantly enhanced plant height, leaf area index and dry matter production after 25 days of sowing (DAS). All yield contributing characters viz., filled achenes capitulum^{-1}, head diameter and 1000-seed weights were maximum with 60 kg S ha^{-1} over 30 kg S ha^{-1}. Seed and stalk yield with 60 kg S ha^{-1} were significantly greater than those of 30 kg S ha^{-1}. Similarly, oil content and oil yield with 60 kg S ha^{-1} was 2 and 10.5 % over 30 kg S ha^{-1}. Application of FYM at the rate of 10 and 20 t ha^{-1} was at par with each other but showed significant improvement in the plant height, leaf area index and dry matter production of sunflower after 25 days of sowing over no FYM. FYM @10 and 20 t ha^{-1} increased the oil yield by 11 and 5.4 %, respectively over no application.

Adebayo *et al*. (2012) found that cassava/poultry manure 3:1 significantly recorded higher plant height at 4 WAP, but significantly had low stem and root dry matter weight. However, cow dung (CD) significantly produced maximum flower diameter (12.13cm) and head weight (39.30g) at harvest.

Waqas *et al*. (2017) reported that highest achene yield (2955.5 kg ha^{-1}), biological yield (12857 kg ha^{-1}), 1000-achenes weight (64.9 g), head diameter (31.10 cm), plant height (157.70 cm) were obtained by applying highest dose 150:90:60 NPK kg ha^{-1}.

Mahapatra *et al*. (2021) found that application of (Soil test based fertilizer recommendation) STBFR + FYM @ 5 t/ha recorded significantly highest growth parameters, seed (2.59 t ha^{-1}) and oil yield (1114 kg ha^{-1}) of sunflower which remained at par with RDF + FYM @ 5 t ha^{-1} + S @ 40 kg ha^{-1} + B @ 0.02%. Highest gross (`141084 t ha^{-1}) and net returns (85406 t ha^{-1}) were recorded with STBFR + FYM @ 5 t ha^{-1}.

Krishnaprabu (2015) reported that application of recommended dose of fertilizer along with pressmud @ 5 t ha^{-1} and combine with foliar application of MnSO4 @ 0.5% on 40 and 60 DAS recorded the maximum seed yield of sunflower compared with other treatments.

Khatik and Dikshit (2001) found that the highest seed yield (2.6 t ha^{-1}) was recorded in the treatment where RDF of NPK was applied with 10 t ha^{-1} compost. Similarly, maximum energy yield, protein content (33.15%), oil content (47.15%) and oil yield (7kg ha^{-1}) were obtained in this treatment, NPK and S uptake was significantly raised due to different treatments compared to control. Availability of NPK and S was found, to have increased due to use of organic manures whether used alone or in combination with fertilizers (RDF of NPK) as compared to inorganic sources and control.

Siddiqu *et al*. (2009) stated that the tallest plant height, maximum stem girth, largest head diameter, most seeds $head^{-1}$, heaviest seed weight $head^{-1}$, largest seed index and best seed yield (1738.0 kg ha^{-1}) were observed under application of 90-45-45 NPK with 15-1.5 Zn-B kg ha^{-1} (N applied as fertigation). This study reported that the incorporation of 90-45-45 kg ha^{-1} (N as fertigation) with 15-1.5 Zn-B kg ha^{-1} to be the optimum fertilizer dose for sunflower growth and yield.

Waghmare *et al*. (2022) reported that the growth parameters of sunflower viz., plant height, number of functional leaves, dry matter production per plant were influenced significantly with soil application of 100% NPK + FYM @ 5 t ha^{-1} along with ZnSO4 and FeSO4 @ 20 kg ha^{-1} and over the other treatments. The yield and yield components of sunflower were also found to be higher with the soil application of 100% NPK + FYM @ 5 t ha^{-1} along with ZnSO4 and FeSO4 @ 20 kg ha^{-1} and recorded significantly higher mean head diameter per plant, seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during November 2020 to March 2021. This chapter deals with a concise description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analysis.

3.1 Geographical location

The experiment was carried out in rabi season at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1 207. The experimental field was located at $90^0$22' E longitude and 23°77' N latitude at an altitude of 8.6 meters above the sea level. The experimental site was situated under the agro-ecological region of "Madhupur Tract" (AEZ No. 28). The geographical location is presented in Appendix I.

3.2 Soil

The farm (experimental field) belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and adequate sunshine was available during the experimental period. Soil samples from 0-15 cm depths were accumulated from experimental field. The analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological, chemical and physical properties of the soil are presented in Appendix II.

3.3 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall combined with moderately low temperature during the rabi season (October-March). The weather data regarding temperature, rainfall, relative humidity and sunshine hour were collected from the weather station, Agargaon during the study period at the experimental site which is presented in Appendix III.

3.4 Seeds and variety

The variety of sunflower used for the present study was BARI sunflower-3. The required seeds for the experiment were collected from the Bangladesh Agricultural

Research Institute (BARI), Joydebpur, Gazipur. The seeds were healthy, well matured and free from mixture of other seeds, weed seeds and extraneous materials. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The plant height of this variety ranges from 90-95 cm. Leaves are dark green and seed are black color. Maximum seed yield is 2.1-2.4 ton/ ha. It is an annual, erect plant, leaf size medium with a strong taproot which prolific lateral spread of surface roots. Stems are usually round early in the season, angular and woody later in the season, and usually unbranched. Sunflower leaves are phototropic and will ensue the sun's rays with a lag of 120 behind the sun's azimuth. This property has been shown to accelerate light interception and possibly photosynthesis. The variety made up of 1,000 to 2,000 individual flowers joined at a common receptacle. In temperate regions, sunflower requires approximately 11 days from planting to emergence, 33 days from emergence to head visible, 27 days from head visible to first anther, 8 days from first to last anther, and 30 days from last anther to maturity. It was found that the variety completed its life cycle in 90-110 days (Krishi Diary, 2019).

3.5 Treatments

Three levels of organic manure and four levels of inorganic fertilizer and their interaction were used in the experiment. These were:

(A) Three levels of organic manure,

i. OM_0 = Control (Without manure)

ii. OM_1 = Cow dung (10 t ha^{-1})

iii. OM_2 = Vermicompost (5 t ha^{-1})

(B) Four levels of inorganic fertilizer,

i. F_0 = Control (Without fertilizer)

ii. F_1 = 50% Recommended dose of fertilizer

iii. F_2 = 75% Recommended dose of fertilizer

iv. F_3 = Recommended dose of fertilizer

(C) Interaction between organic manure and inorganic fertilizer was -

i. $OM_0 \times F_0$

ii. $OM_O \times F_1$

iii. $OM_0 \times F_2$

iv. $OM_0 \times F_3$

v. $OM_1 \times F_0$

vi. $OM_1 \times F_1$

vii. $OM_1 \times F_2$

viii. $OM_1 \times F_3$

ix. $OM_2 \times F_0$

x. $OM_2 \times F_1$

xi. $OM_2 \times F_2$

xii. $OM_2 \times F_3$

3.6 Land preparation

The experimental land was ploughed with a tractor followed by harrowing to achieve a desirable tilth. All uprooted weeds and stubbles of the previous crop were removed from the experimental field. The land was finally prepared with power tiller to ensure a good land preparation. The land was evened by tractor drawn leveler.

3.7 Experimental design

The experiment was laid out following split plot design (SPD) with 3 replications. Here organic manure is the main plot and inorganic fertilizer in the sub plot. The size of unit plot was 2 m x 1.75 m. The total number of treatments was (3 Levels of organic fertilizers × 4 levels of chemical fertilizers) 12 and the number of plots were 36. The experimental layout is presented in Appendix IV.

3.8 Fertilizer dose and application

Cowdung and vermicompost was applied @ 10 and 5 t ha^{-1}. These were applied in the field at the time of final land preparation.

The chemical fertilizers were applied according to the treatments. As such, there were 4 levels of fertilizer combinations as follows -

i. 50% recommended fertilizer dose of sunflower (Treatment, F_1).

This level comprised the following -

Urea = 90 kg ha^{-1}

TSP = 80 kg ha^{-1}

MP = 65 kg ha^{-1}

Gypsum = 75 kg ha^{-1}

ZnSO4 = 4 kg ha^{-1}

Boric Acid = 5 kg ha^{-1}

MgSO4 = 40 kg ha^{-1}

ii. 75% recommended fertilizer dose of sunflower (Treatment, F_2). This level comprised the following -

Urea = 135 kg ha^{-1}

TSP = 120 kg ha^{-1}

MP = 97.5 kg ha^{-1}

Gypsum = 112.5 kg ha^{-1}

ZnSO4 = 6 kg ha^{-1}

Boric Acid = 7.5 kg ha^{-1}

MgSO4 = 60 kg ha^{-1}

iii. 100% recommended fertilizer dose of sunflower (Treatment, F_3). This level comprised the following -

Urea = 180 kg ha^{-1}

TSP = 160 kg ha^{-1}

MP = 130 kg ha^{-1}

Gypsum = 150 kg ha^{-1}

$ZnSO4 = 8 kg ha^{-1}$

Boric Acid = $10 kg ha^{-1}$

$MgSO4 = 80 kg ha^{-1}$

One half (1/2) amount of urea, whole amount of TSP, MOP and others were applied at the time of final land preparation. Rest half of the urea was applied as top dress during 21 days first time and second time at 42 days after seed sowing.

3.9 Germination test

Three layers of filter paper were placed on four Petridishes. Each petridish contained 100 seeds. Germination percentage was calculated by using the following formula.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds taken for germination}} \times 100$$

3.10 Seed rate and seed sowing

Seeds were treated with Bavistin before sowing the seeds to monitor the seed borne disease. The seed rate of BARI sunflower-3 @ 10 kg/ha. After final land preparation the seeds were sown on the furrow on 15th November, 2020. Row to row distance of 50 cm and plant to plant distance of 30 cm. 2/3 seeds are sown in a hill at 3 cm depth of the soil. Seeds were covered properly with soil.

3.11 Intercultural operation

3.11.1 Thinning and gap filling

Thinning of excess seedling was done within 15-20 days after emergence to maintain the population number. Gap filling was done within 10-14 days after sowing.

3.11.2 Weeding

Two hand weedings were done. First time weeding was done at 21 days and second time at 41 days after emergence

3.11.3 Application of irrigation water

Two light irrigations were given at 30 and 60 days after sowing. After irrigation the sunflower was top-dressed. Before ripening the field was remained dry for all the treatments.

3.11.4 Plant protection measures

The sunflower crop was infested by some insect - pest and diseases. Therefore, contact insecticide (Malathian @ 22.2 mm per 10 litres of water. Sevin 85 WP @ 5 g / kg seed, Dursban 20 EC (, 2 mm/L water, Rovral 50 WP 2g/L water) was given.

3.12 Harvesting and sampling

At full maturity, the sunflower crop was harvested plot wise on March 9, 2021. Before harvesting, five plants of sunflower from each plot were selected randomly and uprooted these 5 plants were used to take yield attributes data. Crop of each plot was harvested separately and marked with tags, brought to the threshing floor and sun dried for three days. After threshing seeds. these were then weighed separately to record the seed yield which was converted to t/ha.

3.13 Recording of data

i. Plant height (cm)
ii. SPAD value
iii. Dry weight per plant (g)
iv. Diameter of head (cm)
v. Number of developed seeds head^{-1}
vi. 1000 seeds weight (g)
vii. Seed yield (t ha^{-1})
viii. Harvest index (%)

3.14 Procedure of recording data

The details of data recordings are given below

A. Plant height (cm)

The height of three plants were measured from the ground level to tip of the plants and averaged. It was collected at 25, 45, 65, 85 days after sowing and at harvest separately.

B. Dry plant weight (g)

Three plants at 25, 40, 50 and 75 days after sowing were collected and dried in an oven at 70° C for 48 hours. The dried samples were then weighed and averaged.

C. SPAD value

It was taken from three plants at 25, 40, 55 and 75 days after sowing separately by SPAD meter.

D. Diameter of head (cm)

Diameter of head was measured from five plants and then averaged. This was taken after harvest time.

E. Number of developed seeds/head

The number of developed seeds/head were counted from five plants and then averaged.

F. 1000 seeds weight (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and the mean weight was expressed in gram.

G. Seed yield (t ha^{-1})

The mature head of the harvested plants were collected. Seeds were threshed, dried, weighed and the weight was converted to t ha^{-1}. The seed yields were recorded at 12% moisture level.

H. Stover yield (t ha^{-1})

After separation of seeds from plants, the straw and shell from harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

I. Biological yield (t ha^{-1})

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

J. Harvest index (%)

Harvest index was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain Yield (t ha}^{-1}\text{)}}{\text{Biological Yield (t ha}^{-1}\text{)}} \times 100$$

3.15 Statistical Analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIONS

Effect of organic and inorganic fertilizers on growth, yield attributes and yield of sunflower have been presented and discussed in this chapter. Result of different organic and inorganic fertilizers and their combined applications on growth, yield attributes and yield of sunflower have been presented in the tables and figures.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of organic manure

Plant height is a crucial aspect of the crop plant's vegetative stage that indirectly affects crop plant yield. Sunflower plant height varied greatly depending on the organic manure at different day after sowing (DAS). The results showed that the effect of organic manure on plant height was significant at 45 DAS to at harvest (Fig. 1). At early growth stage at 25 DAS no significant variation in plant height was observed due to treatment variation. Cowdung as organic manure 10 tons per hectare for treatment OM_1 gave the tallest plant (50.54 cm) at 45 DAS, while control condition OM_0 showed the shortest plant (40.59 cm). The tallest plant (86.12 cm) was observed from treatment OM_1 and the shortest (76.74 cm) plant was from the OM_0 treatment at 65 DAS. At 85 DAS the tallest (88.42 cm) plant was recorded from the treatment OM_1 which was statistically similar (84.15 cm) with treatment OM_2 and the shortest (78.96 cm) plant was obtained from the OM_0 treatment. At harvest OM_1 gave the tallest (81.73 cm) plant which was statistically similar (76.54 cm) with OM_2 treatment, while the treatment OM_0 performed the shortest plant (72.22 cm). The results indicated that cowdung and vermicompost organic manure created favorable condition for growth and development for increase of plant height than control i.e. no organic manure. This may be due to the availability of essential nutrients for the plants of sunflower.

Effect of inorganic fertilizer

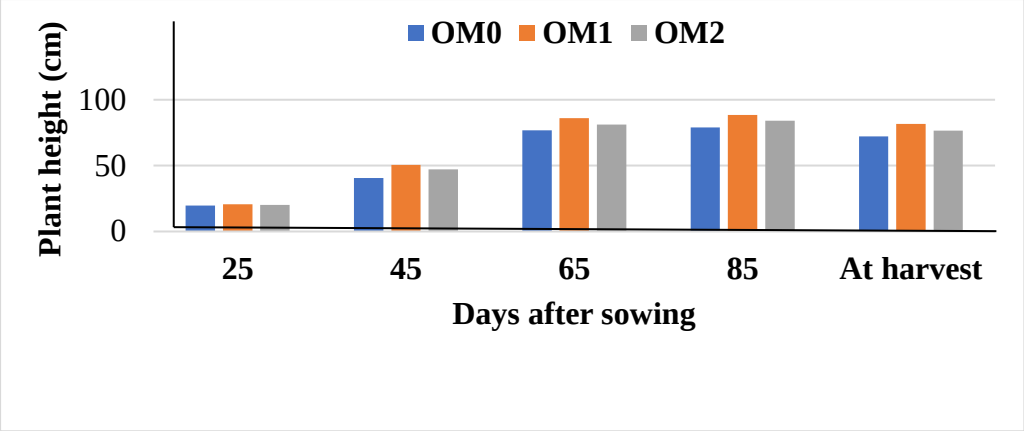
Plant height was significantly increased by inorganic fertilizer from 25 DAS to at harvest. Height was observed to increase steadily as the crop aged up to harvest (Fig. 2). Experimental result revealed that at 25 DAS the treatments F_3 showed highest

plant height (21.97 cm) which was statistically similar with treatment F_2 (20.98 cm), where F_0 (17.76 cm) showed the lowest plant height. At 45 DAS F_3 showed highest plant height (51.213 cm) which was statistically similar with treatment F_2 (49.17 cm), where F_0 showed the lowest plant height (37.85 cm). F_3 and F_2 treatments showed numerically the highest plant height at 65 DAS (86.10 cm and 83.71 cm, respectively), where F_0 showed the lowest plant height (75.92 cm). At 85 DAS treatments F_3 and F_2 showed the highest plant height (90.53 cm and 87.12 cm, respectively) and F_0 showed the lowest plant height (75.92 cm). At harvest treatments F_3 and F_2 showed the highest plant height (83.04 cm and 80.05 cm) and treatment F_0 showed the lowest plant height (69.81 cm) which was statistically similar with treatment F_1 (74.41 cm). Poonia (2000) and Siddiqui *et al*. (2009) also showed the similar result which supported the present finding and reported that among the treatments, RDF substantially recorded maximum plant height.

Interaction effect of organic and inorganic fertilizer

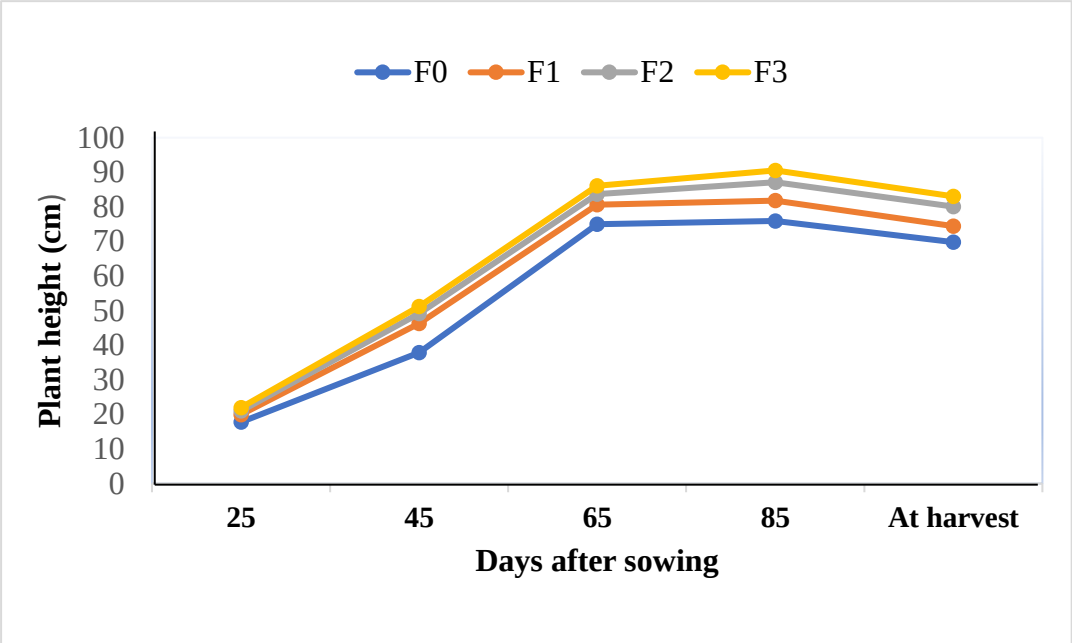
The interaction effect of organic and inorganic fertilizer on plant height was significant at different days after sowing (Table 1). It was observed that at 25 DAS the highest plant height was recorded in the treatment combination of OM_1F_3 (22.47 cm) which was statistically simiar with OM_2F_3 (22.23 cm), OM_1F_2 (21.65 cm), OM_0F_3 (21.19 cm), OM_0F_2 (21 cm), OM_1F_1 (20.59 cm), OM_2F_2 (20.30 cm) and OM_2F_1 (19.78 cm). On the other hand, lowest plant height was recorded with the treatment combination of OM_0F_0 (17.01 cm) which was statisticaly similar with OM_2F_0 (17.97 cm), OM_1F_0 (18.31 cm) and OM_0F_1 (19.43 cm). Treatment combination OM_1F_3 gave the tallest plant (55.93 cm) at 45 DAS, which was statistically similar with OM_1F_2 (53.60 cm) and OM_2F_3 (52.30 cm). Control condition OM_0F_0 showed the shortest plant (30.44 cm) which was statistically similar with treatment combinations OM_0F_1 (42.90 cm), OM_0F_2 (43.60 cm) and OM_1F_0 (43.81 cm). At 65 DAS the tallest plant (91.16 cm) was observed from treatment combination OM_1F_3 which was statistically similar with treatment combination OM_1F_2 (87.17 cm), OM_2F_3 (85.15 cm), OM_1F_1 (84.52 cm) and OM_2F_2 (84.50 cm). The shortest plant (69.55 cm) was from the OM_0F_0 treatment combination which was statistically similar with treatment combinations OM_2F_0 (73.86 cm) and OM_0F_1 (76 cm). At 85 DAS the tallest (95.20 cm) plant was recorded from the treatment OM_1F_3 which was statistically similar with treatment combinations OM_1F_2 (92.25 cm), OM_2F_3 (89.97 cm), OM_1F_1 (87.4 cm),

OM_2F_2 (86.7 cm) and OM_0F_3 (86.43 cm). The shortest plant (72.32 cm) was obtained from the OM_0F_0 treatment combination which was statistically similar with OM_0F_1 (74.67 cm), OM_2F_0 (76.63 cm) and OM_1F_0 (78.82 cm) treatment combinations. At harvest OM_1F_3 gave the tallest plant (88.21 cm) which was statistically similar with OM_1F_2 (85.26 cm), OM_2F_3 (82.11 cm), OM_1F_1 (79.68 cm), OM_2F_2 (79.40 cm) and OM_0F_3 (78.80 cm) treatment combinations, while the treatment combination OM_0F_0 performed the shortest (65.38 cm) plant which was statisticay similar with OM_0F_1 (69.20 cm), OM_2F_0 (70.30 cm), OM_1F_0 (73.75 cm) and OM_2F_1 (74.35 cm). These results revealed that the application of cowdung with higher dose of inorganic fertilizers and vermicompost with higher dose of inorganic fertilizers were influential nutrients for increasing the plant height.



Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 1. Effect of organic manure on plant height of sunflower at different DAS (LSD $_{(0.05)}$ = NS, 2.08, 1.77, 7.0 and 5.90 at 25, 45, 65, 85 and harvest, respectfully)



Here, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF

Figure 2. Effect of inorganic fertilizer on plant height of sunflower at different DAS (LSD $_{(0.05)}$ = 1.48, 2.92, 5.04, 5.20 and 5.14 at 25, 45, 65, 85 DAS and harvest respectfully)

Table 1. Interaction effect of organic and inorganic fertilizer on plant height at different days after sowing (DAS) of sunflower

Treatment combinations	Plant height (cm) at				
	25 DAS	**45 DAS**	**65 DAS**	**85 DAS**	**Harvest**
$OM_0 \times F_0$	17.010 e	30.44 g	69.55 e	72.32 f	65.38 e
$OM_0 \times F_1$	19.43 b-e	42.90 ef	76.0 c-e	74.66 ef	69.22 de
$OM_0 \times F_2$	21.0 a-c	43.60 ef	79.45 b-d	82.40 b-e	75.50 b-d
$OM_0 \times F_3$	21.19 ab	45.41 de	81.97 bc	86.43 a-d	78.80 a-c
$OM_1 \times F_0$	18.31 c-e	43.81 d-f	81.61 b-d	78.81 c-f	73.75 b-e
$OM_1 \times F_1$	20.59 a-d	48.83 b-d	84.52 ab	87.40 a-c	79.68 a-c
$OM_1 \times F_2$	21.65 ab	53.60 ab	87.17 ab	92.25 ab	85.26 a
$OM_1 \times F_3$	22.47 a	55.93 a	91.16 a	95.20 a	88.21 a
$OM_2 \times F_0$	17.97 de	39.30 f	73.86 de	76.63 d-f	70.30 c-e
$OM_2 \times F_1$	19.78 a-e	47.10 c-e	81.41 b-d	83.30 b-e	74.35 b-e
$OM_2 \times F_2$	20.30 a-d	50.31 bc	84.50 ab	86.70 a-c	79.40 a-c
$OM_2 \times F_3$	22.23 ab	52.30 ab	85.15 ab	89.97 ab	82.11 ab
LSD (.05)	**2.58**	**4.82**	**8.74**	**10.39**	**9.67**
CV (%)	**7.45**	**6.39**	**6.27**	**6.27**	**6.76**

In the column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF.

4.1.2 Dry weight per plant

Effect of organic manure

Dry weight of sunflower plant progressively increased by organic manure from 25 DAS to 75 DAS (Fig. 3). It was observed that at 25 DAS the highest dry weight per plant was recorded in the treatment of OM_1 (0.79 g) and control condition OM_0 gave the lowest (0.60 g) dry weight per plant which was statistically similar with treatment OM_2 (0.63 g). The height dry weight per plant was observed from treatment OM_1 (4.64 g) and the lowest dry weight per plant was from the treatment OM_0 (3.24 g) at 50 DAS. At 75 DAS the height dry weight per plant was recorded from the treatment OM_1 (14.86 g) which was statistically similar with treatment OM_2 (12.74 g) and the lowest dry weight per plant was obtained from the treatment OM_0 (9.83 g). Further it was observed that dry weight per plant was increased by giving cow dung and vermicompost.

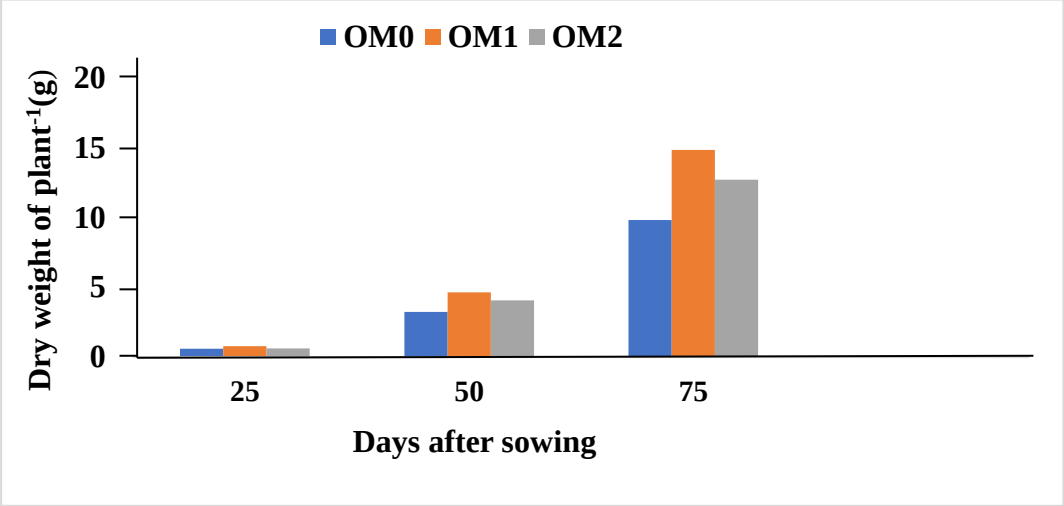
Effect of inorganic fertilizer

The effect of inorganic fertilizer was found positive and significant in producing dry matter production in sunflower. Dry weight per plant gradually increased with increased level of inorganic fertilizers from 25 DAS to 75 DAS (Fig. 4). The figure showed that at 25 DAS the treatment F_3 showed highest dry weight per plant (0.81 g) while treatment F_0 (0.50 g) showed the lowest dry weight per plant. At 50 DAS treatment F_3 showed highest dry weight per plant (4.86 g) which is statistically identical with treatment F_2 (4.61 g). Where F_0 showed the lowest dry weight per plant (2.61 g). Treatment F_3 showed highest dry weight per plant (15.76 g) where F_0 showed the lowest dry weight per plant (9.03 g) at 75 DAS. It was observed that dry weight per plant was increased with increasing level of inorganic fertilizers.

Interaction effect of organic and inorganic fertilizer

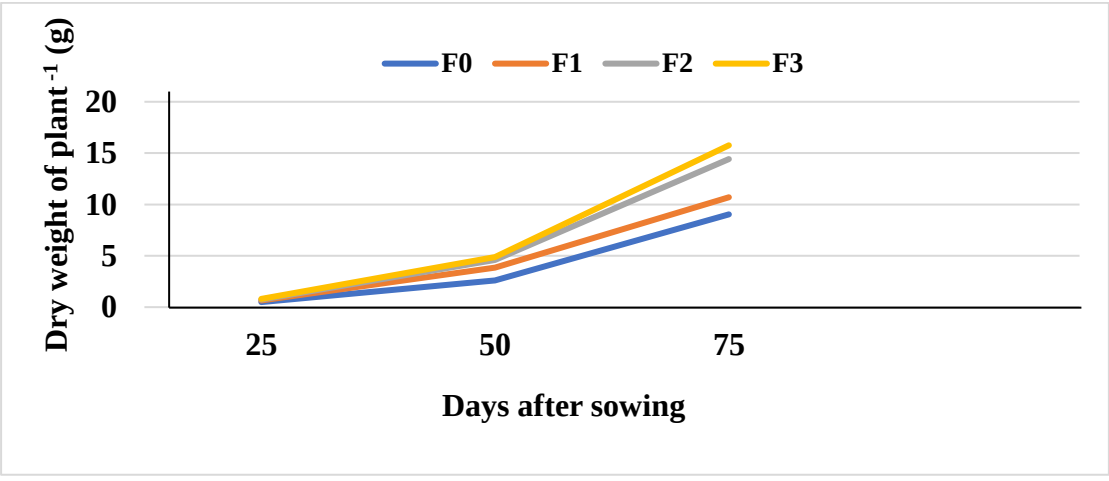
The treatment combination of organic and inorganic fertilizer was significant in producing dry weight plant^{-1} of sunflower (Table 2). At 25 DAS the highest dry weight per plant was recorded in the treatment combination of OM_1F_3 (0.89 g) which was not significantly different from OM_1F_2 (0.86 g), OM_1F_1 (0.83 g) and OM_0F_3 (0.79 g). On the other hand, lowest plant height was recorded with the treatment combination OM_0F_0 (0.40 g) which was significantly similar with treatment combination OM_2F_0 (0.52 g). Treatment combination OM_1F_3 gave the height dry

weight per plant (5.33 g) at 50 DAS, which was significantly similar with OM_1F_2 (5.29 g) and OM_2F_3 (4.86 g), while control condition OM_0F_0 showed the lowest dry weight per plant (1.64 g). The highest dry weight per plant (18.74 g) was observed from treatment combination OM_1F_3 which was statistically similar with treatment combination OM_1F_2 (16.84 g) at 75 DAS. The lowest dry weight per plant (6.13 g) was from the treatment combination OM_0F_0 at 75 DAS which was statistically similar with treatment combination OM_0F_1 (8.10 g).



Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 3. Effect of organic manure on dry weight of plant^{-1} of sunflower at different DAS (LSD $_{(0.05)}$ = 0.10, 0.31 and 2.51 at 25, 50 and 70 DAS, respectfully)



Here, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF

Figure 4. Effect of inorganic fertilizer on dry weight of plant^{-1} of sunflower of at different DAS (LSD (0.05) = 0.06, 0.29 and 1.29 at 25, 50 and 70, respectfully)

Table 1. Interaction effect of organic and inorganic fertilizer on dry weight of plant^{-1} at different days after sowing (DAS) of sunflower

Treatment combinations	Dry weight plant^{-1}(g) at		
	25 DAS	50 DAS	75 DAS
$OM_0 \times F_0$	0.40 g	1.64 f	6.13 h
$OM_0 \times F_1$	0.53 f	3.00 e	8.10 gh
$OM_0 \times F_2$	0.66 de	3.83 cd	11.91 d-f
$OM_0 \times F_3$	0.79 a-c	4.40 b	13.18 c-e
$OM_1 \times F_0$	0.57 ef	3.30 de	11.35 ef
$OM_1 \times F_1$	0.83 ab	4.63 b	12.51 c-f
$OM_1 \times F_2$	0.86 ab	5.29 a	16.84 ab
$OM_1 \times F_3$	0.89 a	5.33 a	18.74 a
$OM_2 \times F_0$	0.52 fg	2.90 e	9.62 fg
$OM_2 \times F_1$	0.60 ef	3.86 c	11.48 ef
$OM_2 \times F_2$	0.68 c-e	4.70 b	14.51 b-d
$OM_2 \times F_3$	0.73 b-d	4.86 ab	15.36 bc
LSD (.05)	**0.14**	**0.53**	**3.15**
CV (%)	**8.75**	**7.39**	**10.45**

In the column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF.

4.1.3 SPAD value

Effect of organic manure

SPADE value of plant was significantly increased by organic manure from 25 DAS to 70 DAS (Fig. 5). It was observed that at 25 DAS the highest SPAD value of plant was recorded in the treatment of OM_1 (31.06) and control condition OM_0 gave the lowest (27.76) SPAD value of plant. The height SPAD value of plant was observed from

treatment OM_1 (35.29) and the lowest SPAD value of plant was from the treatment OM_0 (32.29) at 40 DAS. At 55 DAS the height SPAD value of plant was recorded from the treatment OM_1 (36.26) which was statistically similar with treatment OM_2 (35.05) and the lowest SPAD value of plant was obtained from the treatment OM_0 (33.56). At 70 DAS the height SPAD value (37.04) of plant was recorded from the treatment OM_1 which was statistically similar (35.98) with treatment OM_2 and the lowest SPAD value of plant was obtained from the treatment OM_0 (34.14). The results indicated that cow dung and vermicompost increased SPAD value of plant.

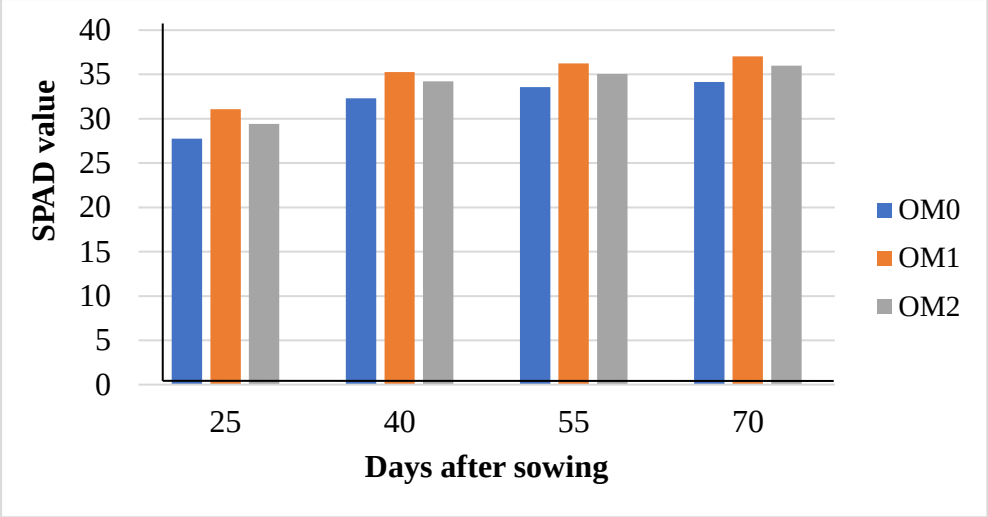
Effect of inorganic fertilizer

SPAD value of plant was significantly increased by inorganic fertilizer from 25 DAS to 70 DAS (Fig. 6). The figure showed that at 25 DAS the treatment F_2 (31.05) showed highest SPAD value of plant which was statistically similar with treatment F_3 (30.55). Where F_0 (27.15) showed the lowest SPAD value. At 40 DAS F_2 showed highest SPADE value (36) which was statistically identical with treatment F_3 (35.12). Where F_0 showed the lowest SPAD value (31.51). F_2 showed highest SPAD value (36.98) at 55 DAS which was statistically similar with treatment F_3 (35.88). Where F_0 showed the lowest SPAD value (32.78). At 70 DAS F_2 showed the highest SPAD value (37.72), which was statistically similar with treatment F_3 (36.96) and F_0 (32.96) showed the lowest spade value of plant.

Interaction effect of organic and inorganic fertilizer

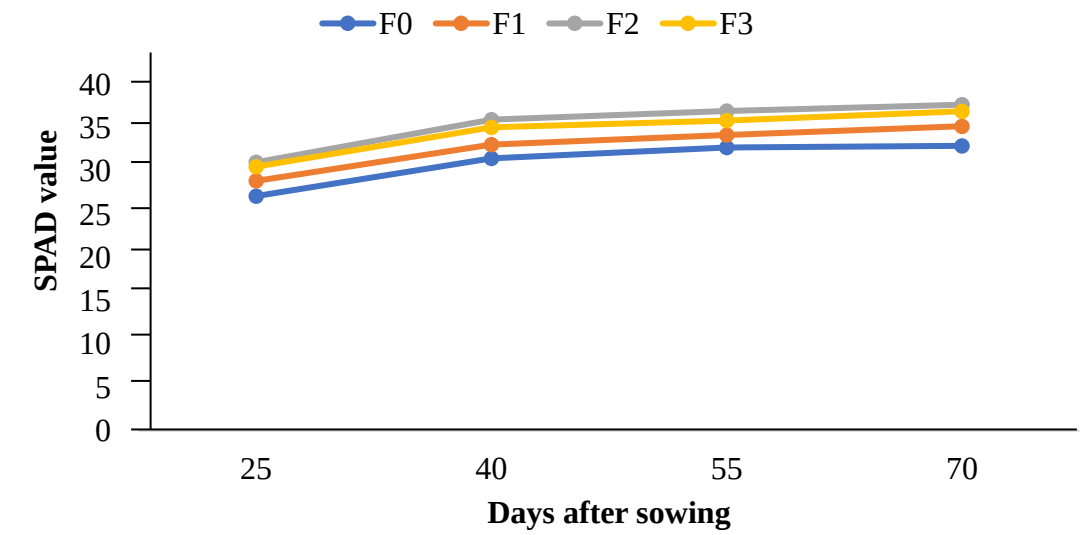
The interaction effect of organic and inorganic fertilizer on SPAD value of plant was significant at different days after sowing (Table 3). It was observed that at 25 DAS the highest SPAD value of plant was recorded in the treatment combination of OM_1F_3 (32.67) which was not significantly different from OM_1F_2 (32.26), OM_2F_2 (31.70) and OM_2F_3 (30.26). On the other hand, lowest SPAD value of was recorded with the treatment combination of OM_0F_0 (25.36) which was significantly similar with OM_2F_0 (26.86). Treatment combination OM_1F_2 (37.10) gave the height SPAD value of plant at 40 DAS, which was significantly similar with OM_1F_3 (36.82), OM_2F_2 (36.52) and OM_2F_3 (35.14) while control condition OM_0F_0 (30.24) showed the lowest SPAD value of plant. The height SPAD value of plant was observed from treatment combination OM_1F_2 (38.63) which was statistically similar with treatment combination OM_1F_3 (37.50) and OM_2F_2 (37.1), while the lowest SPAD value of plant

was from the treatment combination OM_0F_0 (31.75) at 55 DAS. At 70 DAS the height SPAD value of plant was recorded from the treatment OM_1F_2 (39.60) which was statistically similar with treatment combinations OM_1F_3 (38.58), OM_2F_2 (38.15) and OM_2F_3 (37.10). The lowest SPAD value of plant recorded from the treatment combination OM_0F_0 (31.86) which was statistically similar with treatment combinations OM_2F_0 (33.22), OM_1F_0 (33.8) and OM_0F_1 (34.10).



Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 5. Effect of organic manure on SPAD value of sunflower at different DAS (LSD $_{(0.05)}$ = 1.67, 0.97, 1.42 and 1.63 at 25, 40, 55 and 70 DAS, respectfully)



Here, F_0 = Control (Without fertilizer), F_1= 50% RDF, F_2 = 75% RDF and F_3= RDF.

Figure 6. Effect of inorganic fertilizer on SPAD value of sunflower at different DAS (LSD $_{(0.05)}$ =1.22, 1.41, 1.80 and 1.42 at 25, 40, 55 and 70 DAS, respectfully)

Table 2. Interaction effect of organic and inorganic fertilizer on SPAD value at different days after sowing (DAS) of Sunflower

Treatment combination	SPAD value at			
	25 DAS	**40 DAS**	**55 DAS**	**70 DAS**
$OM_0 \times F_0$	25.36 f	30.24 h	31.75 d	31.86 f
$OM_0 \times F_1$	27.76 de	31.14 gh	32.70 cd	34.10 d-f
$OM_0 \times F_2$	29.20 c-e	34.38 c-e	35.200 bc	35.40 c-e
$OM_0 \times F_3$	28.73 c-e	33.40 d-g	34.65 b-d	35.20 c-e
$OM_1 \times F_0$	29.23 c-e	32.70 f-g	33.90 cd	33.80d-f
$OM_1 \times F_1$	30.09 b-d	34.52 b-e	35.00 bc	36.16 b-d
$OM_1 \times F_2$	32.26 a	37.10 a	38.63 a	39.60 a
$OM_1 \times F_3$	32.67 a	36.82 ab	37.50 ab	38.58 ab
$OM_2 \times F_0$	26.86 ef	31.60 f-h	32.65 cd	33.22 ef
$OM_2 \times F_1$	28.86 c-e	33.60 d-f	34.95 bc	35.43 c-e
$OM_2 \times F_2$	31.70 ab	36.52 a-c	37.10 ab	38.15 ab
$OM_2 \times F_3$	30.26 a-c	35.14 a-d	35.50 bc	37.10 a-c
LSD (.05)	**2.47**	**2.32**	**3.04**	**2.68**
CV (%)	**4.21**	**4.20**	**5.22**	**4.04**

In the column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF.

4.2 Yield and yield attributing characters

4.2.1 Diameter of head

Effect of organic manure

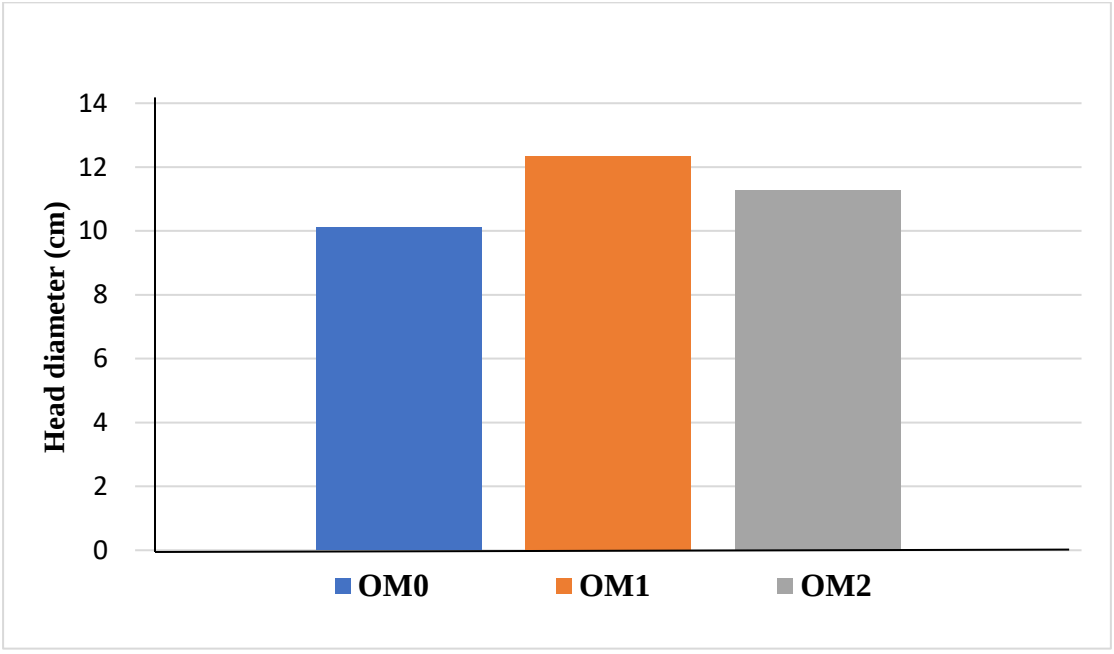
Different organic manure treatments significantly influenced head diameter of sunflower (Fig. 7). The highest head diameter was obtained from treatment OM_1 (12.35 cm) and the lowest from OM_0 (10.12 cm).

Effect of inorganic fertilizer

Head diameter of sunflower showed significant differences due to different level of inorganic fertilizers treatment (Fig. 8). The maximum head diameter of sunflower was found from F_3 (12.63 cm), which was statistical similar with treatment F_2 (12.36 cm) and the minimum was obtained from treatment F_0 (9.51). Malik *et al*. (2004) and Naseem *et al.* (2011) also reported that head diameter of sunflower was increased by increasing level of N, P and K.

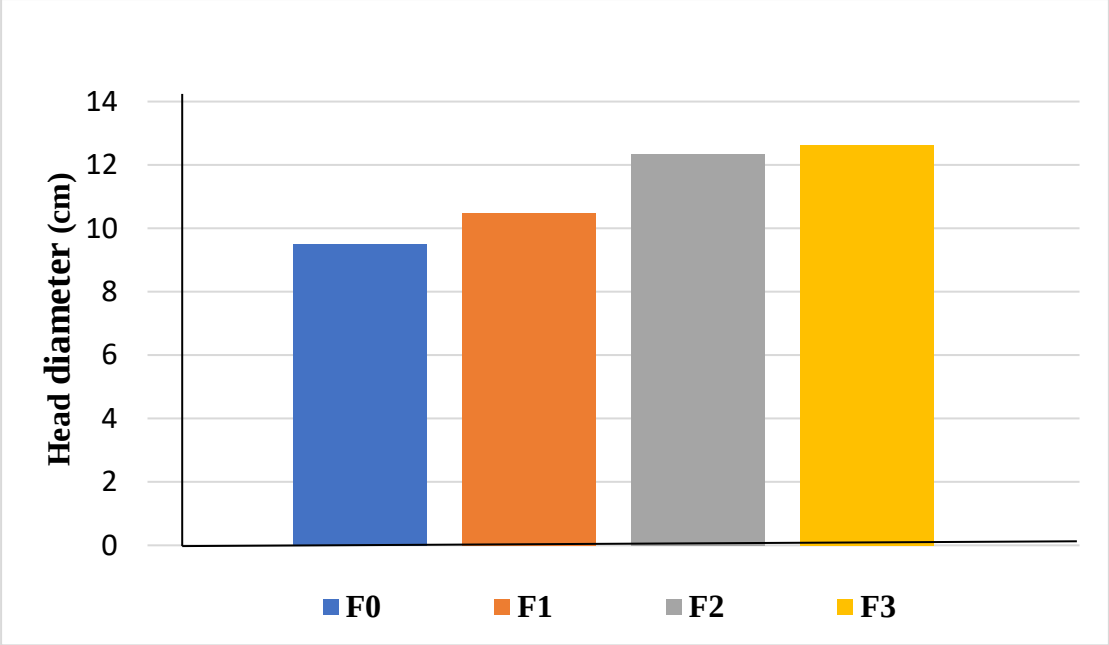
Combined effect of organic and inorganic fertilizer

The combined effect of organic and inorganic fertilizer on head diameter of sunflower was significant (Table 4). The treatment combination OM_1F_3 (13.71 cm) gave the highest head diameter of sunflower which was statistically similar with OM_1F_2 (13.29 cm). The lowest head diameter of sunflower was obtained from the OM_0F_0 (8.28 cm) treatment combination.



Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 7. Effect of organic manure on head diameter of sunflower (LSD $_{(0.05)}$ = 0.69)



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Here, F_0 = Control (Without fertilizer), F_1= 50% RDF, F_2 = 75% RDF and F_3= RDF.

Figure 8. Effect of inorganic fertilizer on head diameter of sunflower (LSD $_{(0.05)}$ = 0.51)

4.2.2 Number of seeds per head

Effect of organic manure

The effect of two types of organic manures on the number of seeds per head was significant (Fig. 9). The highest number of seeds per head was obtained from OM_1 (401.67) treatment, which was statistically similar with treatment OM_2 (379.67). The lowest number of seeds per head was produced by control treatment OM_0 (335.75). It was observed that the application of co dung up to 10 t ha^{-1} and vermicompost up to 5 t ha^{-1} increased number of seeds per head.

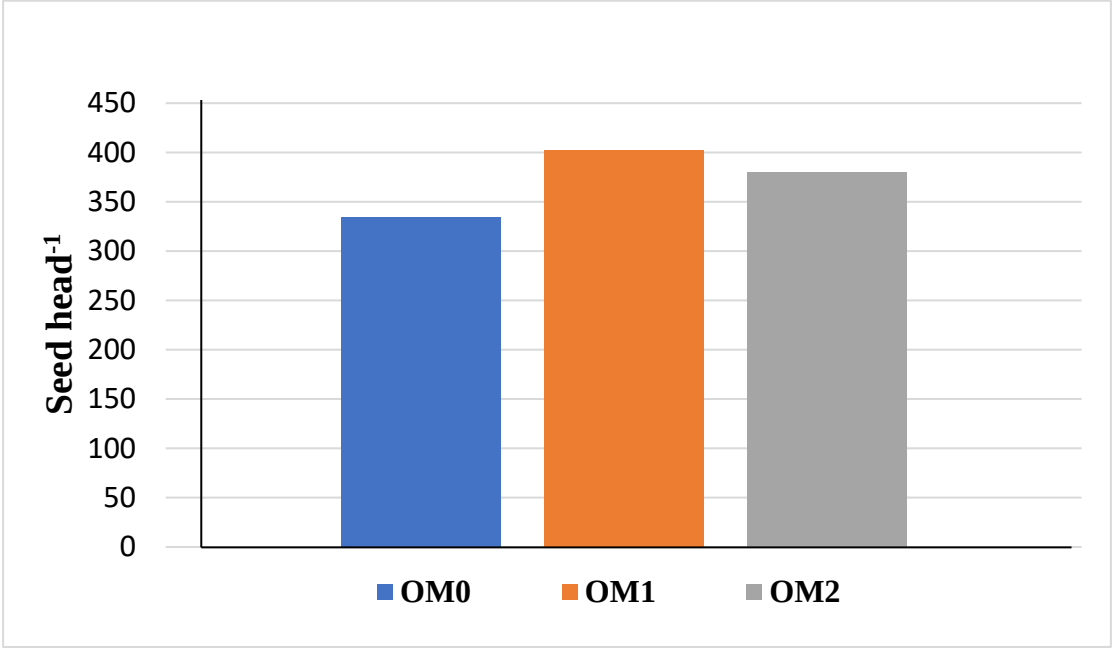
Effect of inorganic fertilizer

The effect of different levels of inorganic fertilizer on the number of seeds per head was found positive and significant (Fig. 10). Number of seeds per head gradually increased with increasing level of inorganic fertilizers up to the highest level of the present trial. The highest number of seeds per head was obtained with the application of treatment F_3 (422.78) which was statistically similar with treatment F_2 (414.62). The lowest number of seeds per head was found in control treatment F_0 (284). Further it was observed that number of seeds per head was increased with increasing level of

inorganic fertilizers up to higher level. Sadiq *et al*. (2000) also advocated that NPK increased number of grains head^{-1}.

Interaction effect of organic and inorganic fertilizer

The interaction effect of the treatment combinations of organic and inorganic fertilizer on number of seeds per head was significant (Table 4). The highest seeds per head was found in OM_1F_3 (453.33), which was not statistically different from OM_1F_2 (443.67), OM_2F_3 (429.33) and OM_2F_2 (422.67) treatment combinations. The lowest number of seeds per head was produced by the control treatment OM_0F_0 (245.33), which was statistically similar with the effect of treatment combination of OM_2F_0 (291.33).



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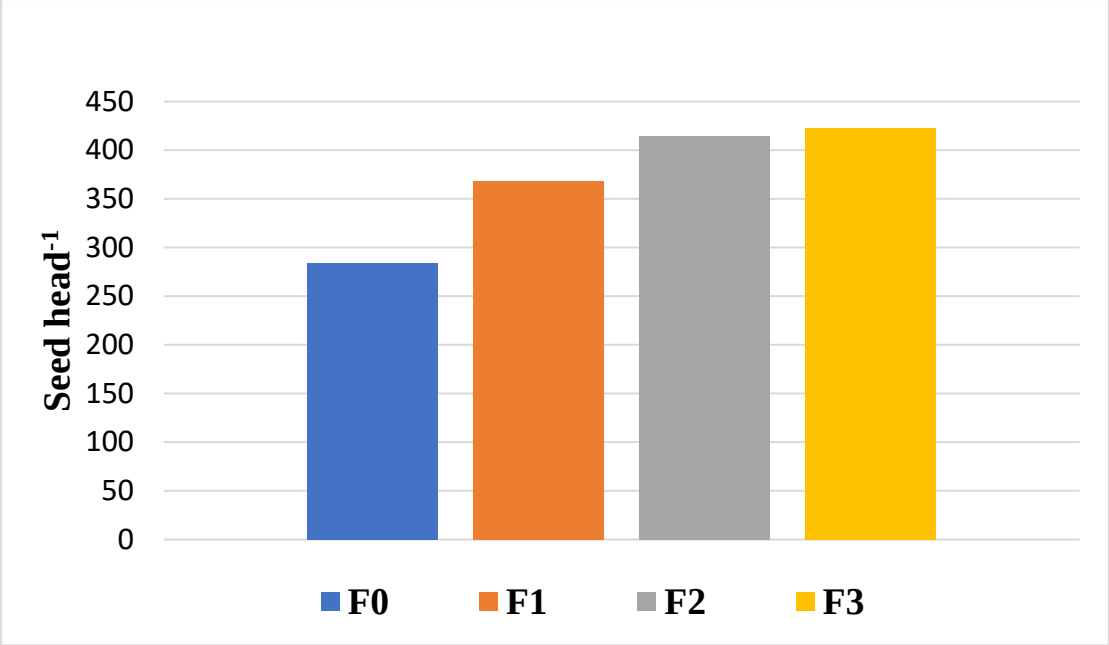
Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 9. Effect of organic manure on seed head^{-1} of sunflower (LSD $_{(0.05)}$ = 41.1)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 10. Effect of inorganic fertilizer on seed head^{-1} of sunflower (LSD $_{(0.05)}$ = 16.56)

4.2.3 1000 seeds weight

Effect of organic manure

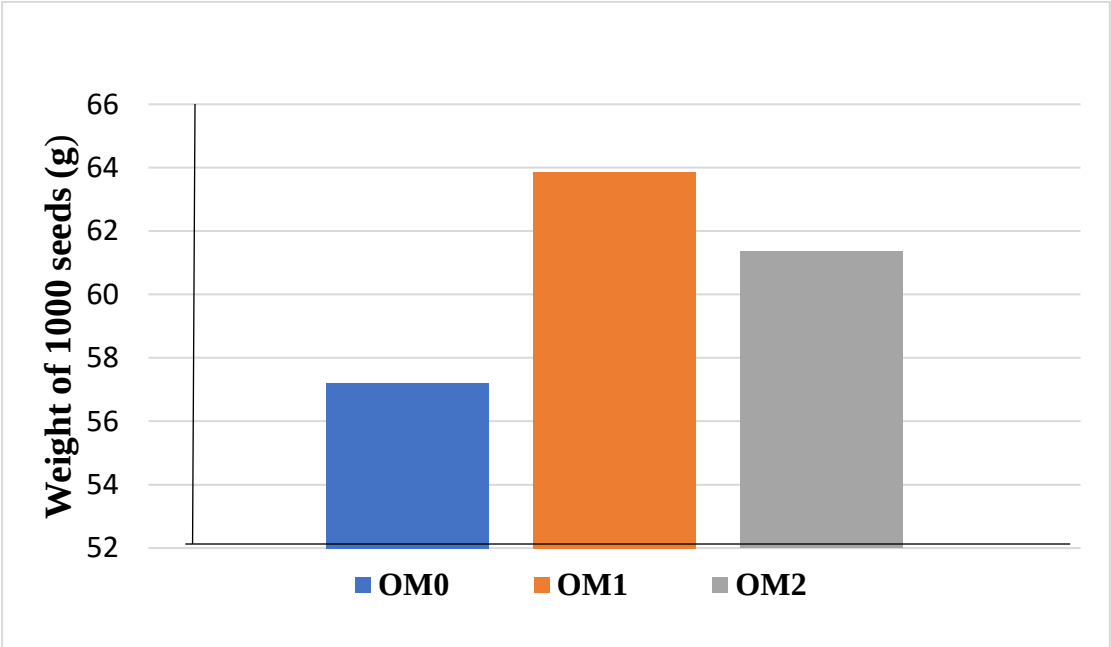
Statistically significant variations were observed for weight of 1000 seeds of sunflower due to different organic manure treatments (Fig. 11). The highest weight of 1000 seeds of sunflower was found from OM_1 (63.87 g), which was statistically similar with treatment OM_2 (61.36 g) and the lowest weight was recorded from OM_0 (57.21 g).

Effect of inorganic fertilizer

Statistically significant variations were observed for weight of 1000 seeds of sunflower due to different inorganic fertilizer treatments (Fig. 12). The highest weight of 1000 seeds of sunflower was found from F_3 (64.54g), which was statistically similar with treatments F_2 (64.02g) and F_1 (60.05 g). The lowest weight was recorded from F_0 (54.64 g). Arif *et al.* (2003) also reported that by increasing NPK levels, 1000 seeds weight of sunflower was increased.

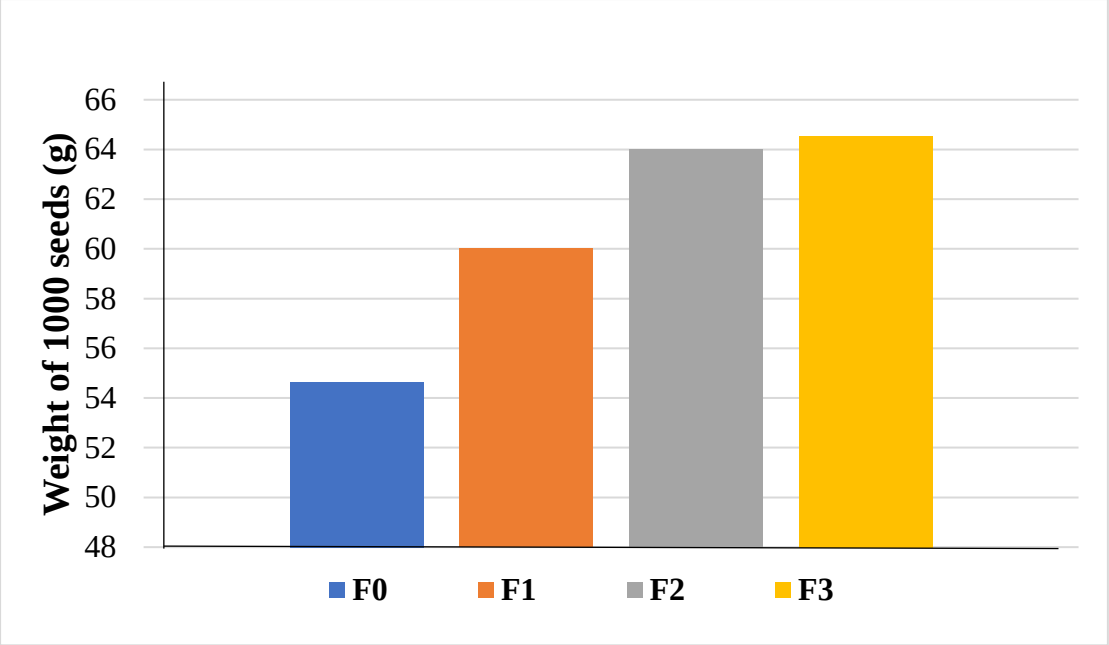
Interaction effect of organic and inorganic fertilizer

The interaction effect of the treatment combinations of organic and inorganic fertilizer on weight of 1000 seeds of sunflower was significant (Table 4). The highest weight of 1000 seeds of sunflower was found in OM_1F_3 (66.84 g), which was statistically identical with all the treatments except OM_0F_1, OM_2F_0 and OM_0F_0. The lowest number of seeds per head was produced by the control treatment OM_0F_0 (8.58 g), which was statistically similar with the effect of treatment combination of OM_2F_0 (56.06 g).



Here, OM_0 = Control (Without manure), OM_1 = Cowdung and OM_2 = Vermicompost

Figure 11. Effect of organic manure on weight of 1000 seeds of sunflower (LSD $_{(0.05)}$ = 6.03)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 12. Effect of inorganic fertilizer on weight of 1000 seeds of sunflower (LSD $_{(0.05)}$ = 4.68)

4.2.4 Seed yield

Effect of organic manure

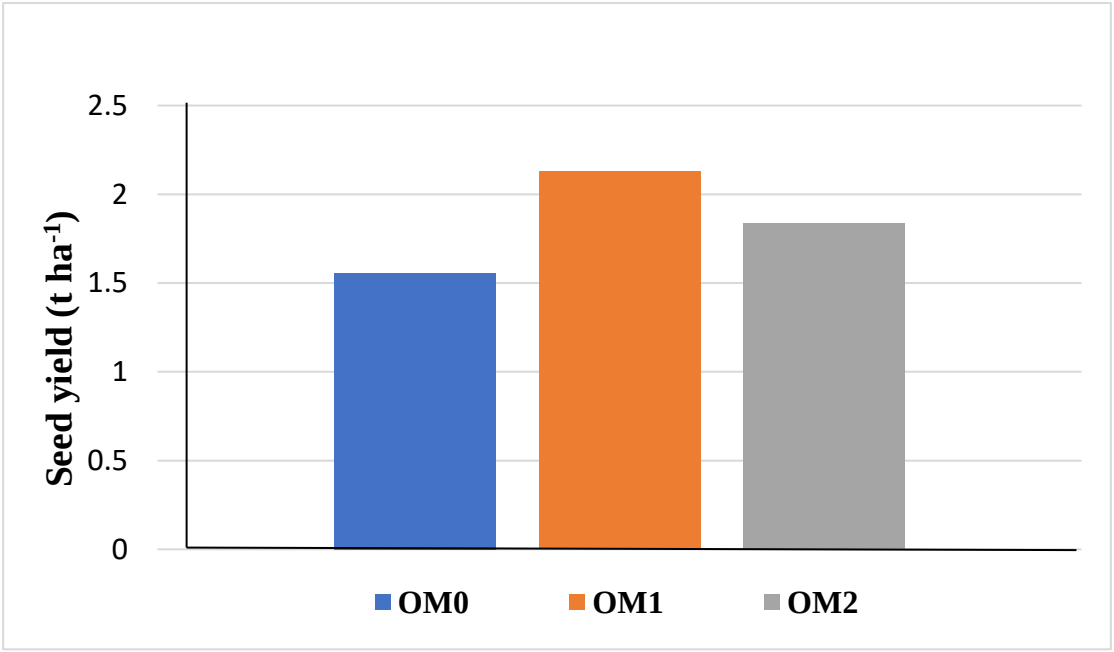
Seed yield of sunflower varied significantly due to different organic manure treatments under the trial (Fig. 13). The highest yield was observed from OM_1 (2.13 t ha^{-1}) and the lowest yield was found from OM_0 (1.56 t ha^{-1}). This indicates that OM_1 treatment was superior than OM_0 treatment by producing 36.54 % heavier seed.

Effect of inorganic fertilizer

Statistically significant variations were observed for seed yield of sunflower due to different level of inorganic fertilizers treatment (Fig. 14). The highest yield was observed from F_3 (2.19 t ha^{-1}), which was however, statistically similar with F_2 (2.12 t $ha^{-1)}$ and the lowest yield was found from F_0 (1.35 t ha^{-1}) treatment. Osman and Ewed (2010) also conveyed that RDF fertilizers enhanced yield of sunflower in comparison to control.

Interaction effect of organic and inorganic fertilizer

The combined effect of organic and inorganic fertilizer on seed yield of sunflower was significant (Table 5). The treatment combination OM_1F_3 (2.47 t ha^{-1}) gave the maximum seed yield of sunflower which was statistically similar with treatment combinations OM_1F_2 (2.40 t $ha^{-1)}$ and OM_2F_3 (2.24 t ha^{-1}). The minimum seed yield of sunflower was obtained from the OM_0F_0 (1.1 t ha^{-1}) treatment combination which was statistically similar with treatment OM_2F_0 (1.32 t ha^{-1}).



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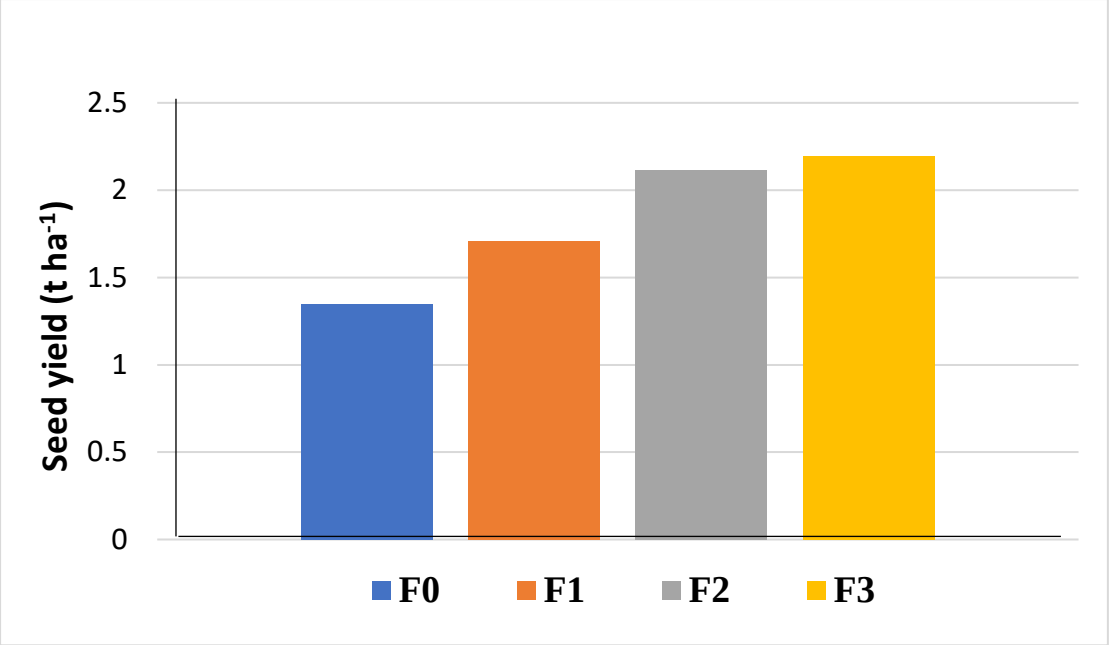
Here, OM_0 = Control (Without fertilizer), OM_1 = Cowdung and OM_2 = Vermicompost

Figure 13. Effect of organic manure on seed yield of sunflower (LSD $_{(0.05)}$ = 0.16)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 14. Effect of inorganic fertilizer on seed yield of sunflower (LSD $_{(0.05)}$ = 0.12)

4.2.5 Stover yield

Effect of organic manure

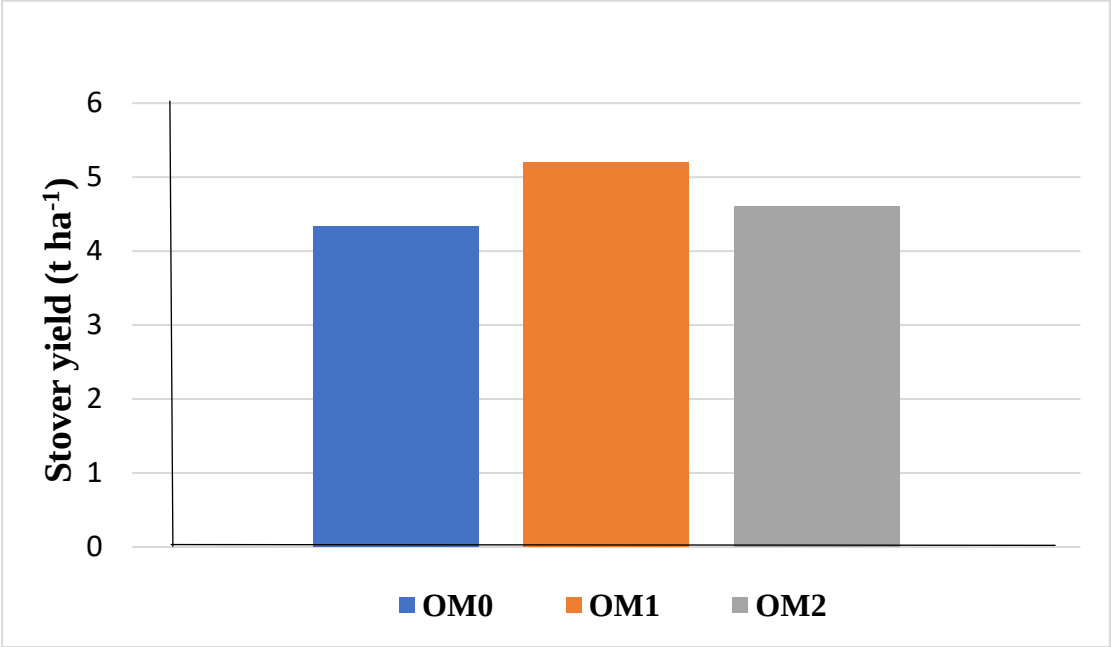
Stover yield of sunflower showed significant differences due to different organic treatments (Fig. 15). The highest stover yield was recorded from OM_1 (5.02 t ha^{-1}) which was however, statistically similar to OM_2 (4.61 t ha^{-1}) and the lowest relative yield was found from OM_0 (4.33 tha^{-1}).

Effect of inorganic fertilizer

Stover yield of sunflower showed significant differences due to different level of inorganic treatments (Fig.16). The maximum stover yield was recorded from F_3 (5.42 t ha^{-1}) which was statistically similar F_2 (5.26 t ha^{-1}) and the lowest stover yield was found from F_0 (3.55 t ha^{-1}) treatment.

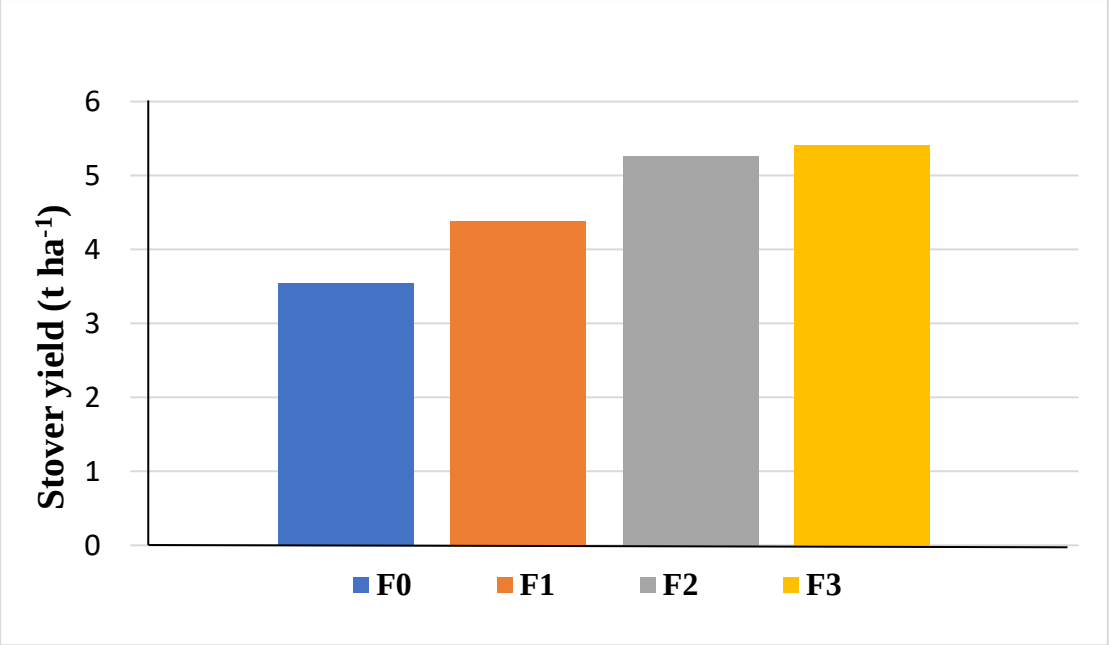
Interaction effect of organic and inorganic fertilizer

The interaction effect of the treatment combinations of organic and inorganic fertilizers on stover yield of sunflower was significant (Table 5). The highest stover yield of sunflower was found in OM_1F_3 (5.71 t ha^{-1}), which was statistically similar with treatment combinations OM_1F_2, OM_2F_3, OM_2F_2, OM_0F_3 and OM_0F_2. The lowest number of stover yield of sunflower was produced by the control treatment combination OM_0F_0 (3.2 t ha^{-1}), which was statistically similar with the effect of treatment combinations of OM_2F_0 and OM_1F_0.



Here, OM_0 = Control (Without fertilizer), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 15. Effect of organic manure on stover yield of sunflower (LSD $_{(0.05)}$ = 0.64)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 16. Effect of inorganic fertilizer on stover yield of sunflower (LSD $_{(0.05)}$ = 0.31)

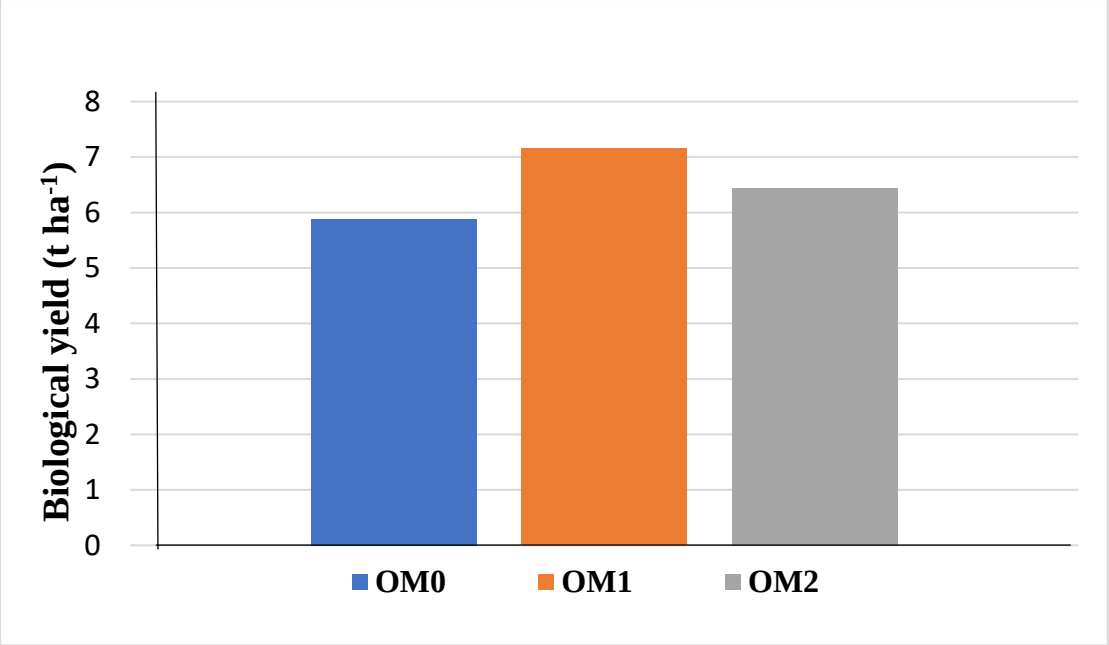
4.2.6 Biological yield

Effect of organic manure

Statistically significant variations were observed for biological yield of sunflower due to different organic manures treatment (Fig 17). The highest biological yield of sunflower was found from OM_1 (7.15 t ha^{-1}), which was statistically simiar with treatment OM_2 and the lowest biological yield was recorded from OM_0 (5.89 t ha^{-1}).

Effect of inorganic fertilizer

Statistically significant variation was observed for biological yield of sunflower due to different level of inorganic fertilizers treatment (Fig. 18). The highest biological yield of sunflower was found from F_3 (7.61 t ha^{-1}), which was statistically simiar with treatment F_2. The lowest biological yield was recorded from F_0 (4.89 t ha^{-1}). Soleymani *et al*. (2013) also reported that biological yield increased by applying RDF of fertilizer.



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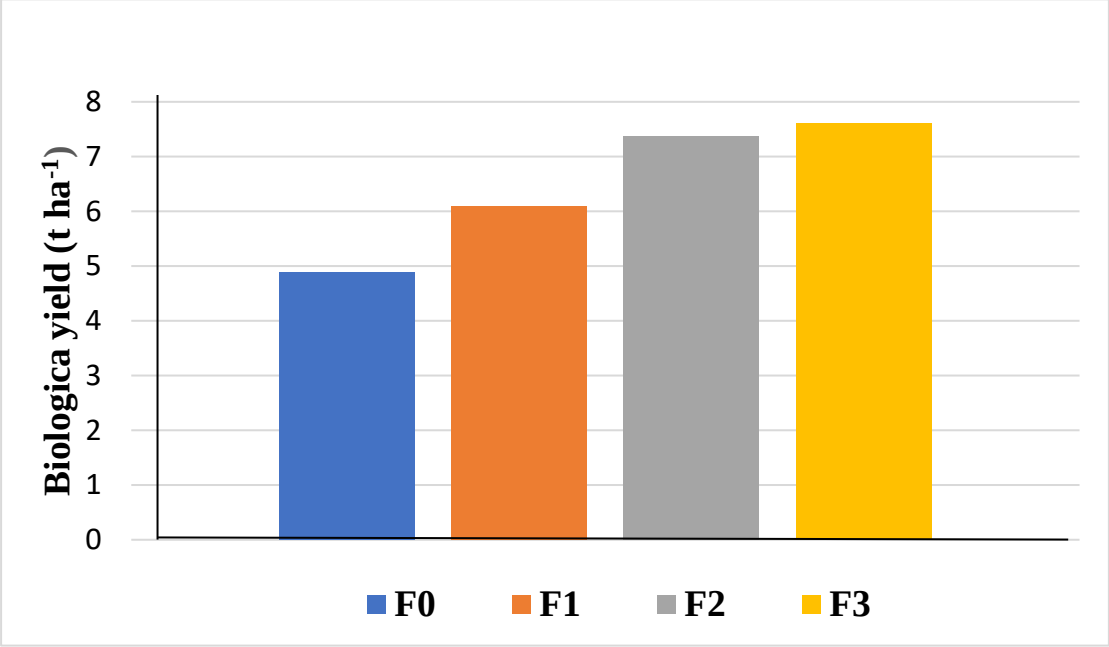
Here, OM_0 = Control (Without fertilizer), OM_1 = Cowdung and OM_2 = Vermicompost.

Figure 17. Effect of organic manure on biological yield of sunflower (LSD $_{(0.05)}$ = 0.87)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 18. Effect of inorganic fertilizer on biological yield of sunflower (LSD $_{(0.05)}$ = 0.48)

Interaction effect of organic and inorganic fertilizer

The interaction effect of the treatment combinations of organic and inorganic fertilizer on biological yield of sunflower was significant (Table 5). The highest biological yield of sunflower was found in OM_1F_3 (8.18 t ha^{-1}), which was statistically similar with treatment combinations OM_1F_2, OM_2F_3 and OM_2F_2. The lowest biological yield of sunflower was produced by the control treatment combination OM_0F_0 (4.3 t ha^{-1}), which was statistically similar with the effect of treatment combination of OM_2F_0.

4.2.7 Harvest index

Effect of organic manure

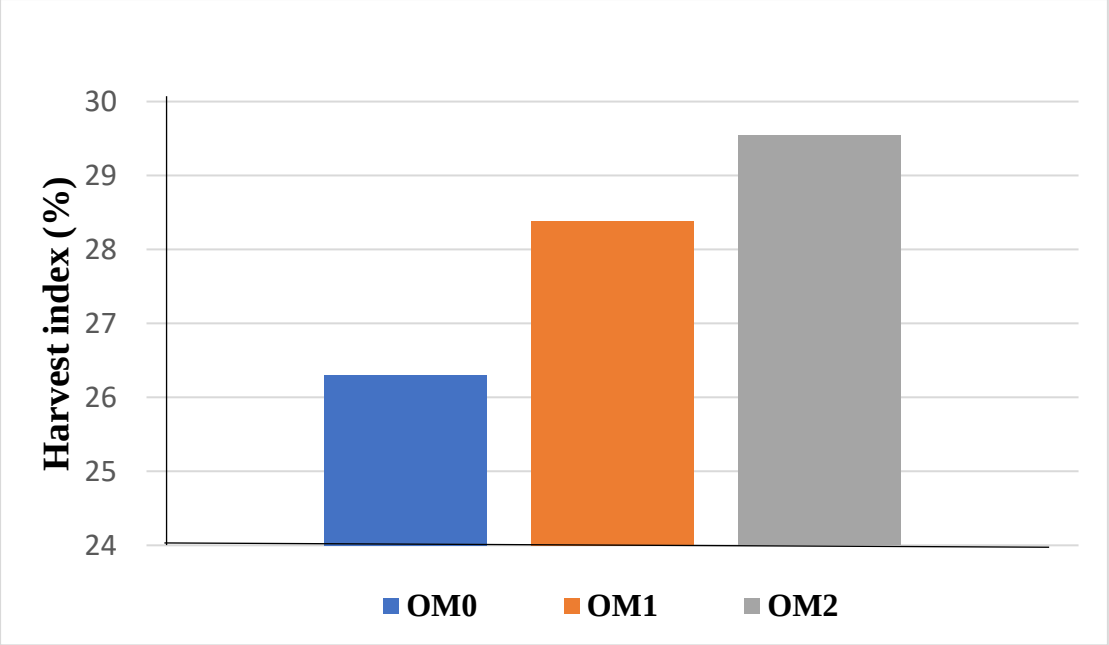
Different organic manure treatment significantly influenced harvest index of sunflower (Fig. 19). The highest harvest index was obtained from treatment OM_1 (29.55 %) which was statistically similar with treatment OM_2 and the lowest from OM_0 (26.35 %).

Effect of inorganic fertilizer

Harvest index of sunflower showed nonsignificant differences due to different level of inorganic fertilizers treatment (Fig. 20).

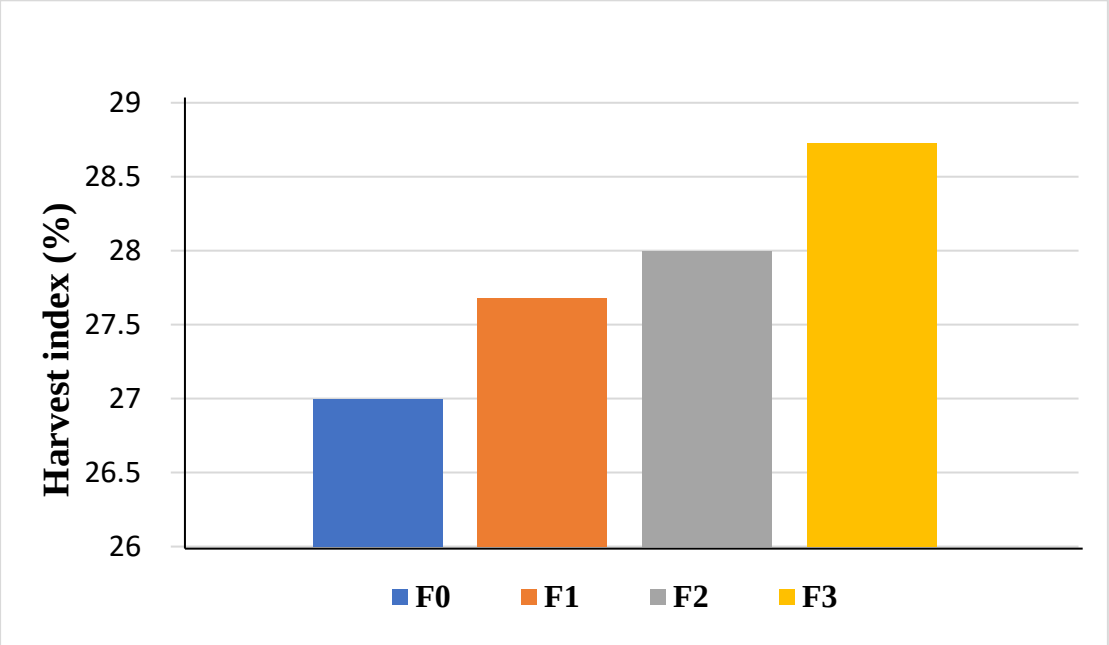
Interaction effect of organic and inorganic fertilizer

The combined effect of organic and inorganic fertilizers on harvest index of sunflower was significant (Table 5). The treatment combination OM_1F_3 (30.2 %) gave the highest harvest index of sunflower which was statistically similar with treatment combinations OM_1F_2, OM_2F_3, OM_1F_0, OM_2F_2, OM_1F_1, OM_2F_1 and OM_2F_0. The lowest harvest index of sunflower was obtained from the OM_0F_0 (25.58 %) treatment combination which was statistically similar with treatment combination OM_0F_1.



Here, OM_0 = Control (Without fertilizer), OM_1 = Cow dung and OM_2 = Vermicompost.

Figure 19. Effect of organic manure on harvest index of sunflower (LSD $_{(0.05)}$ = 1.52)



Here, F0 = Control (Without fertilizer), F1= 50% RDF, F2 = 75% RDF and F3= RDF.

Figure 20. Effect of inorganic fertilizer on harvest index of sunflower (LSD = NS)

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

Treatment combinations	Head diameter (cm)	Seeds head $^{-1}$ (no)	Weight of 1000 seeds (g)
$OM_0 \times F_0$	8.28 i	245.33 g	48.58 d
$OM_0 \times F_1$	9.31 h	334.67 ef	56.69 bc
$OM_0 \times F_2$	11.29 d-f	377.33 cd	61.48 a-c
$OM_0 \times F_3$	11.59 c-e	385.67 b-d	62.09 a-c
$OM_1 \times F_0$	10.66 ef	315.33 f	59.29 a-c
$OM_1 \times F_1$	11.75 cd	394.33 b-d	62.90 a-c
$OM_1 \times F_2$	13.29 ab	443.67 a	66.43 a
$OM_1 \times F_3$	13.71 a	453.33 a	66.84 a
$OM_2 \times F_0$	9.57 gh	291.33 fg	56.05 cd
$OM_2 \times F_1$	10.39 fg	375.33 de	60.54 a-c
$OM_2 \times F_2$	12.49 bc	422.67 a-c	64.14 a-c
$OM_2 \times F_3$	12.60 bc	429.33 ab	64.68 ab
LSD (.05)	**1.03**	**47.63**	**9.18**
CV (%)	**4.66**	**4.49**	**7.77**

In the column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, OM_0 = Control (Without fertilizer), OM_1 = Cowdung and OM_2 = Vermicompost, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF.

Table 5. Interaction effect of organic and inorganic fertilizer on seed yield, stover yield and harvest of sunflower

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$OM_0 \times F_0$	1.10 g	3.20 g	4.30 g	25.58 c
$OM_0 \times F_1$	1.46 ef	4.13d-f	5.59 ef	26.12 c
$OM_0 \times F_2$	1.80 cd	4.93 a-c	6.73 cd	26.75 bc
$OM_0 \times F_3$	1.87cd	5.07 ab	6.94 b-d	26.95 bc
$OM_1 \times F_0$	1.62 de	3.98 e-g	5.60 ef	29.03 ab
$OM_1 \times F_1$	2.02 bc	4.78 b-d	6.81 cd	28.99 ab
$OM_1 \times F_2$	2.40 a	5.61 a	8.01 ab	29.96 a
$OM_1 \times F_3$	2.47 a	5.71 a	8.18 a	30.20 a
$OM_2 \times F_0$	1.32 fg	3.47 fg	4.79 fg	27.55 a-c
$OM_2 \times F_1$	1.64 de	4.23 c-e	5.87 de	27.94 a-c
$OM_2 \times F_2$	2.14 b	5.24 ab	7.38 a-c	29.01 ab
$OM_2 \times F_3$	2.24 b	5.47 ab	7.71 a-c	29.05 ab
LSD (.05)	**0.25**	**0.79**	**1.12**	**2.66**
CV (%)	**6.85**	**6.84**	**7.52**	**5.29**

In the column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.

Here, OM_0 = Control (Without fertilizer), OM_1 = Cowdung and OM_2 = Vermicompost, F_0 = Control (Without fertilizer), F_1 = 50% RDF, F_2 = 75% RDF and F_3 = RDF.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to march 2021 in Rabi season, to study the influence of organic and inorganic fertilizers on growth, yield attributes and yield of sunflower. The experiment consisted of two factors, and followed split plot design with three replications. Factor A: Organic manures (3) viz: OM_0: Control (without manure), OM_1: Cowdung 10 t ha^{-1}, OM_2: Vermicompost 5 t ha^{-1} and Factor B: Chemical fertilizers (4) viz: F_0 = Control (without fertilizer), F_1 = 50% Recommende dose of fertilizer, F_2 = 75% RDF and F_3 = RDF. For the purpose of evaluating the experiment's outcomes, data on various parameters were taen. These data revealed significant variance in sunflower's growth, yield, and yield attributes as a result of organic manure, inorganic fertilizer, and combination of these factors.

Organic and inorganic fertilization at different levels individually influenced plant characters. The individual and interaction effect of organic and inorganic fertilizers on growth, yield and yield attributes were found positive.

In case of organic fertilizers, plant height of sunflower was significantly increased at 45 DAS to at harvest expect at 25 DAS. There was no significant difference at 25 DAS. At 45 DAS the tallest plant (50.54 cm) was produced with cow dung 10 t ha^{-1} (OM_1) and shortest plant (40.59 cm) was found in control treatment. At 65 DAS the tallest plant (86.12 cm) was produced with cowdung 10 t ha^{-1} (OM_1) and shortest plant (76.74 cm) was found in control treatment OM_0. AT 85 DAS the tallest plant (88.42 cm) was produced with cow dung 10 t ha^{-1} (OM_1) and shortest plant (78.96 cm) was found in control treatment OM_0. At harvest the tallest plant (81.73 cm) was produced with cow dung 10 t ha^{-1} (OM_1) and shortest plant (72.22 cm) was found in control treatment OM_0.

In terms of different levels of inorganic fertilizers, F_3 (RDF) treatment showed the highest plant height at 25 DAS (21.96 cm), 45 DAS (51.23 cm), 65 DAS (86.10 cm), 85 DAS (90.53 cm) and at harvest (83.04 cm). While the F_0 (control) treatment showed the lowest plant height at 25 DAS (17.76 cm), 45 DAS (37.85 cm), 65 DAS (75.0 cm), 85 DAS (75.92 cm) and at harvest (69.81 cm). F_2 (75% of RDF) treatment also showed statistically similar result with F_3 treatment.

The treatment combinations of organic and inorganic fertilizers had significant effect on plant height. The tallest plant height was found in OM_1F_3 (cow dung 10 t ha^{-1}+ RDF) treatment combination at 25 DAS (22.47 cm), 45 DAS (55.93 cm), 65 DAS (91.16 cm), 85 DAS (95.2 cm) and at harvest (88.21 cm). The shortest plant height was observed in the control treatment combination OM_0F_0 at 25 DAS (17.01 cm), 45 DAS (39.3 cm), 65 DAS (69.55 cm), 85 DAS (72.32 cm) and at harvest (65.38 cm).

The effect of organic fertilizers on dry weight per plant was influenced significantly. The maximum dry weight per plant was recorded from the treatment OM_1 (cowdung 10 t ha^{-1}) at 25 DAS (0.79 g), 50 DAS (4.64 g) and 75 DAS (14.86 g). Control treatment OM_0 produced the minimum dry weight per plant at 25 DAS (0.60 g), 50 DAS (3.24 g) and 75 DAS (9.83 g).

Inorganic fertilizers had also significant effect on dry weight per plant. The maximum dry weight per plant was recorded from the treatment of F_3 (RDF) at 25 DAS (0.81 g), 50 DAS (4.86 g) and 75 DAS (15.76 g). The minimum dry weight per plant was produced in control treatment (F_0) at 25 DAS (0.60 g), 50 DAS (2.61 g) and 75 DAS (9.03 g).

Combinedly the treatment OM_1F_3 (cowdung 10 t ha^{-1}+ RDF) produced the maximum dry weight per plant at 25 DAS (0.89 g), 50 DAS (5.33 g) and 75 DAS (18.74 g). The minimum dry weight number per plant was obtained from OM_0F_0 (control) treatment combination at 25 DAS (0.40 g), 50 DAS (1.60 g) and 75 DAS (6.13 g). The treatment combinations of organic and inorganic fertilizers on dry weight per plant were significant.

There were significant differences among the different types of organic manure in respect of SPAD value of plant. The highest SPAD value of plant was obtained with the application of cowdung 10 t ha^{-1} (OM_1) at 25 DAS (31.06), 40 DAS (35.29), 55 DAS (36.26) and 70 DAS (37.04). The lowest SPAD value of plant was produced by control treatment (OM_0) at 25 DAS (27.76), 40 DAS (32.29), 55 DAS (33.56) and 70 DAS (34.14). SPAD value of plant gradually increased with days after sowing.

In terms of different levels of inorganic fertilizers, the highest SPAD value of plant was obtained with the application of 75 % RDF (F_2) at 25 DAS (31.05), 40 DAS (36), 55 DAS (34.22) and 70 DAS (35.230). The lowest SPAD value of plant was found in

control treatment (F_0) at 25 DAS (27.15), 40 DAS (31.513), 55 DAS (32.77) and 70 DAS (32.96).

The treatment combinations of organic and inorganic fertiizer on SPAD value of plant were significant. At 25 DAS the highest SPAD value (32.67) of plant was found in treatment combination OM_1F_3 (cowdung 10 t ha^{-1}+ RDF). At 40 DAS (37.10), 55 DAS (38.63) and 70 DAS (39.60) the highest SPAD value of plant was found in treatment combination OM_1F_2 (cow dung 10 t ha^{-1}+ 75 % RDF). The lowest SPAD value of plant was produced by the treatment combination OM_0F_0 (control) at 25 DAS (25.36), 40 DAS (30.24), 55 DAS (31.75) and 70 DAS (31.86).

In case of organic manure, the highest yield attributes and yield of sunflower viz, head diameter (12.35 cm), seeds $head^{-1}$ (401.67), weight of 1000 seeds (63.87 g), seed yield (2.13 t ha^{-1}), stover yield (5.02 t ha^{-1}) and biological yield (7.15 t ha^{-1}) were observed by OM_1 (cowdung 10 t ha^{-1}) treatment. However, this treatment also recorded the highest harvest index (29.55 %) comparable to other treatments. Whereas the lowest yield attributes and yield viz, head diameter (10.127cm), seeds $head^{-1}$ (335.75 no), weight of 1000 seeds (57.21 g), seed yield (1.56 t ha^{-1}), stover yield (4.33 t ha^{-1}) and biological yield (5.89 t ha^{-1}) were observed by OM_0 (control) treatment. Also, this treatment produced the lowest harvest index (26.35 %).

In terms of different levels of inorganic fertilizers, F_3 (RDF) treatment showed the highest head diameter (12.63 cm), seeds $head^{-1}$ (422.78), weight of 1000 seeds (64.54 g), seed yield (2.19 t ha^{-1}), stover yield (5.42 t ha^{-1}) and biological yield (7.61 t ha^{-1}). Whereas the lowest yield attributes and yield viz, head diameter (9.50 cm), seeds $head^{-1}$ (284), weight of 1000 seeds (54.64 g), seed yield (1.35 t ha^{-1}), stover yield (3.55 t ha^{-1}) and biological yield (4.90 t ha^{-1}) were observed by F_0 (control) treatment. Harvest index of sunflower showed nonsignificant differences due to different level of inorganic treatments.

In case of combination, the OM_1F_3 treatment combination demonstrated the maximum head diameter (13.71 cm), seeds $head^{-1}$ (453.33), weight of 1000 seeds (66.84 g), seed yield (2.47 t ha^{-1}), stover yield (5.71 t ha^{-1}), biological yield (8.18 t ha^{-1}) and harvest index (30.2 %), but OM_1F_2 (cowdung 10 t ha^{-1} along with 75% of RDF) was statistically at par with OM_1F_3 in respect of yield and yield attributes parameter. Whereas the lowest head diameter (8.28 cm), seeds $head^{-1}$ (245.33), weight of 1000

seeds (48.58 g), seed yield (1.1 t ha^{-1}), stover yield (3.2 t ha^{-1}), biological yield (4.3 t ha^{-1}) and harvest index (25.58 %) were observed by OM_0F_0 (control) treatment combination.

Conclusion

Based on the above findings, the experimental results revealed that organic and inorganic fertilizers significantly influenced the growth, yield attributing characteristics and seed yield of sunflower.

From the present study, the following conclusion may be drawn –

It may be concluded that cowdung 10 t ha^{-1} or inorganic fertilizer as their 75% recommended dose alone or their combination would help to plant growth and increase its ability to enhanced better yield of sunflower.

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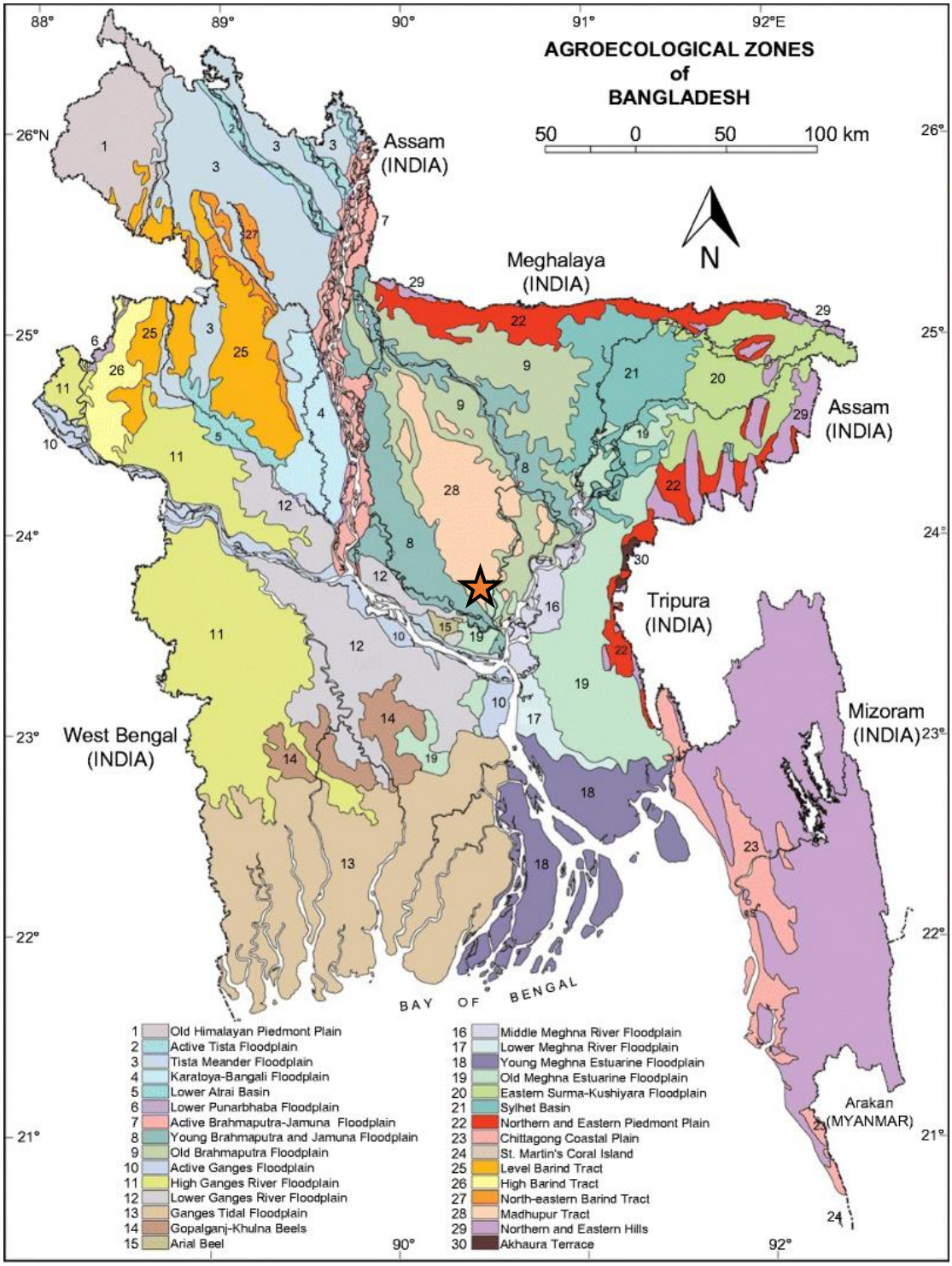
APPENDICES

Appendix I. Map showing the experimental sites under study



★ The experimental site under study

Appendix II. Morphological, physical and chemical characteristics of the soil

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. The initial physical and chemical characteristics of soil of the experimental

Physical characteristics Constituents	**Percent**
Sand (%) (0.0-0.02 mm)	26 %
Silt (1%) (0.02-0.002 mm)	45 %
Clay (%) (<0.002 mm)	29 %
Soil Textural class	Silty loam

Chemical characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Source: Soil Resources Development Institute (SRDI), Dhaka

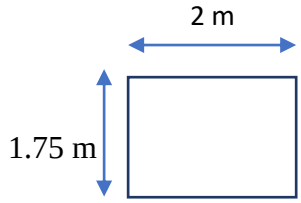
Appendix III. Monthly records of air temperature, relative humidity and rainfall during the period from November 2020 to March 2021

Month (2020-2021)	*Temperature (Maximum, ^{O}C)	*Temperature (Minimum, ^{O}C)	*Relative Humidity (%)	*Rainfall (mm)
November	29.2	20.5	67	9
December	26.4	17	60	9
January	26	15.3	53	2
February	29.8	17.4	45	10
March	32.2	21.8	66	3

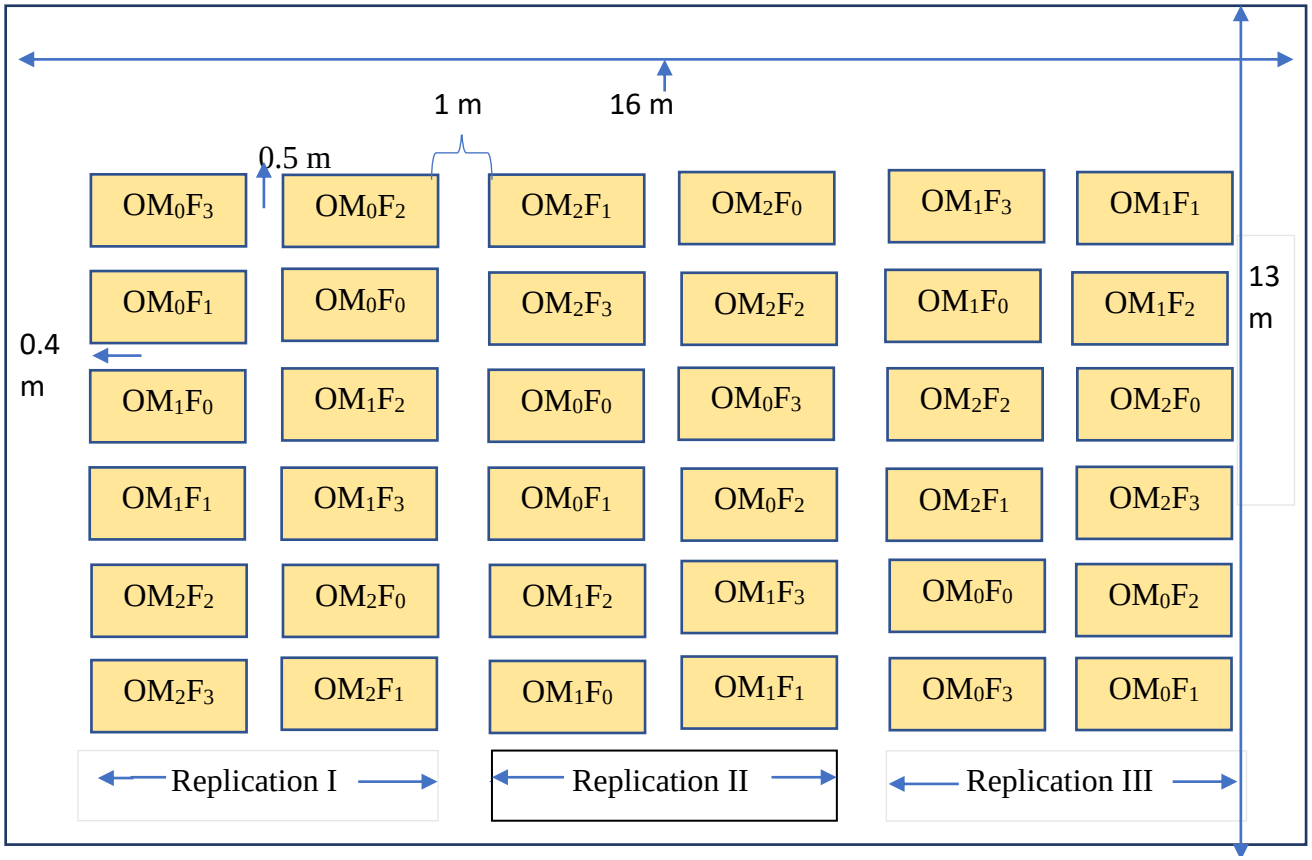
*Monthly average

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout of the experimental field



Plot size: 2 m × 1.75 m



Appendix V. Analysis of variance of the data of plant height of sunflower at different DAS

Sources of variation	Degrees of freedom	Mean square				
		At different days after transplanting				
		25	45	65	85	At harvest
Replication	2	2.6011	444.899	1489.88	1046.97	888.966
Organic manure (A)	2	3.6869*	308.697*	263.60*	269.48*	271.783*
Error	4	2.3445	3.382	2.45	38.18	27.653
Inorganic manure (B)	3	29.1878*	310.985*	206.43*	367.31*	312.272*
Interaction (A*B)	6	0.4993*	7.195*	5.20*	7.20*	1.480*
Error	18	2.2579	8.701	26.00	27.62	27.005

*: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data of dry weight plant^{-1} of sunflower at different DAS

Sources of variation	Degrees of freedom	Mean square		
		At different days after transplanting		
		25	50	75
Replication	2	0.05529	2.46212	23.04880
Organic manure (A)	2	0.12382*	5.98464*	76.58240*
Error	4	0.00811	0.07737	4.9326
Inorganic manure (B)	3	0.15848*	9.16936*	88.75530*
Interaction (A*B)	6	0.00936*	0.11978*	0.8117*
Error	18	0.00429	0.08661	1.70180

*: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data of SPAD value of sunflower at different DAS

Sources of variation	Degrees of freedom	Mean square			
		At different days after transplanting			
		25	40	55	70
Replication	2	110.384	0.5903	1.1265	7.5294
Organic manure (A)	2	32.670*	27.6411*	21.6590*	25.7437*
Error	4	2.194	0.7447	1.5782	2.0917
Inorganic manure (B)	3	28.105*	36.7575*	30.8482*	40.1458*
Interaction (A*B)	6	0.873*	0.3354*	0.7655*	0.9229*
Error	18	1.535	2.0348	3.3260	2.0833

*: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data of head diameter, seeds head^{-1}, weight of 1000 seeds of sunflower

Sources of variation	Degrees of freedom	Mean square		
		Head diameter	**Seeds head^{-1}**	**Weight of 1000 seeds**
Replication	2	14.7556	15371.1	252.214
Organic manure (A)	2	14.9887*	13516.5*	135.557*
Error	4	0.3741	1314.9	28.366
Inorganic manure (B)	3	20.3304*	36440.3*	188.493*
Interaction (A*B)	6	0.0559*	16.0*	6.612*
Error	18	0.2742	659.3	22.350

*: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data of seed yield, stover yield, biological, yield and harvest index of sunflower at different DAS

Sources of variation	Degrees of freedom	Mean square			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.12735	1.51587	2.55880	30.39910
Organic manure (A)	2	0.97488*	1.44564*	4.79000*	31.4130*
Error	4	0.02593	0.32391	0.5928	1.8218
Inorganic manure (B)	3	1.38449*	6.71960*	14.20010*	3.9197*
Interaction (A*B)	6	0.00723*	0.01981*	0.04430*	0.0725*
Error	18	0.01591	0.10136	0.23810	2.21120

*: Significant at 0.05 level of significance

PLATES

Plate 1. Land preparation of the experimental field

Plate 2. Seed sowing of sunflower

Plate 3. Early seedling stage of sunflower

Plate 4: Vegetative stage of sunflower

Plate 5: Flowering stage of sunflower

Plate 6: Collecting data from sunflower plant

Plate 7:Experimental field with signboard

Plate 8: Maturity stage of sunflower