GROWTH AND YIELD PERFORMANCE OF SUNFLOWER AS INFLUENCED BY DIFFERENT ORGANIC FERTILIZERS

A THESIS

BY

RAKIB BIN RAHMAN

Student No. 1601054
Session: 2021-2022
Semester: July-December 2022

MASTER OF SCIENCE
IN
AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,
DINAJPUR-5200

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DEDICATED

TO MY

BELOVED PARENTS

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December, 2022 — *The Author*

Rakib Bin Rahman

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LIST OF ABBREVIATIONS

AEZ	-	Agro-Ecological Zone
BARI	-	Bangladesh Agricultural Research Institute
CV	-	Coefficient of Variation
DAS	-	Days After Sowing
DMRT	-	Duncan's Multiple Range Test
LSD	-	Least Significant Difference
LS	-	Level of Significance
DAP	-	Di-Ammonium Phosphate
RCBD	-	Randomized Complete Block Design
TSP	-	Triple Super Phosphate
Var.	-	Variety
LAI	-	Leaf Area Index
FYM	-	Farm Yard Manure
RD	-	Recommended Dose
RT	-	Reduced Tillage
GM	-	Green Manure
HI	-	Harvest Index
TSW	-	Thousand Seed Weight
CD	-	Cow Dung
PM	-	Poultry Manure
MoP	-	Muriate of Potash
WSB	-	Wheat-Straw Biochar

ABSTRACT

Current soil management strategies are mainly dependent on inorganic chemical-based fertilizers, which caused a serious threat to human health and the environment. The exploitation of beneficial microbes as organic fertilizers has become vital importance in agriculture for their potential role in food safety and sustainable crop production. The eco-friendly approaches inspire application of organic fertilizers leading to improve plant growth, yield performance, and soil behavior quality. Therefore, to study the effect of different organic fertilizers in response to the growth and yield of sunflower, a field experiment was conducted at the research field of the Agronomy Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 during the period from December 2021 to April 2022. Treatments included: T_1 = Control (no application); T_2 = Farm Yard Manure (FYM) @ 2 t ha^{-1}; T_3 = Vermicompost (VC) @ 2 t ha^{-1}; T_4 = Biochar (BC) @ 2 t ha^{-1}; T_5 = Farm Yard Manure (FYM) @ 1 t ha^{-1} + Vermicompost (VC) @ 1 t ha^{-1}; T_6= Farm Yard Manure (FYM) @ 1 t ha^{-1} + Biochar (BC) @ 1 t ha^{-1} and T_7= Vermicompost (VC) @ 1 t ha^{-1} + Biochar (BC) @ 1 t ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The results showed that all the yield attributes were significantly affected by the conjunctive use of different organic fertilizers. Results showed that T_7 had the highest value for plant height (181.0 cm); leaves number $plant^{-1}$ (48.7 no.); fresh weight of leaves $plant^{-1}$ (12.5 g); dry weight $plant^{-1}$ (45.61 g); leaf length (47.61 cm); chlorophyll content (193.67%); flower head diameter (30 cm); fresh and dry weight of flower head (342 g); weight of seed $head^{-1}$ (45.53 g); biological yield (8.07 t ha^{-1}); harvest index (47%); water holding capacity (92%) and seed yield (3.42 t ha^{-1}). The crop under treatment T_6 showed the highest value for stem diameter (11.7 cm); dry weight of leaves $plant^{-1}$ (0.58 g); fresh weight of $plant^{-1}$ (97.8 g); and leaf area index (1.40). Treatment T_5 showed highest performance for fresh and dry seed number $head^{-1}$ (1457 no.) and 1000 seeds weight (85.67 g). Therefore, it was concluded that among the organic fertilizers, vermicompost @ 1 t ha^{-1} + biochar @ 1 t ha^{-1} combined showed more promising results for sunflower growth and yield and the knowledge gained from the research will help us to understand the use of organic fertilizers towards sustainable agriculture in reducing problems associated with the use of chemicals fertilizers.

CHAPTER I
INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an annual oilseed plant of Asteraceae family. Sunflower is a valuable plant both from economic and ornamental points of view. Sunflower is one of the fastest growing oil seed in the world as well as in Bangladesh. It ranks 4th in oil seed crops all area of the world (Adeleke and Balola, 2020). Sunflower oil is the best-consumed vegetable oil at the global level due to its health and economic distinction. The total world cultivation area, and production in 2020/19 and 2019/18 cropping years were 23,839,000 and 24,626,000 ha producing 36,062,000 tons and 42,867,000 tons, respectively (FAO, 2019) for sunflower. It has been estimated that world production of sunflower seeds exceeded 44.7 million tons from 25.5 million hectares of land (2020-2021) cropping years (FAO, 2020). According to the fortune business insight, the global sunflower oil market size was worth $18.5 billion in 2020, and is expected to reach $29.59 billion in 2028, exhibiting a compound annual growth rate (CAGR) of 6.12 percent during the forecast period (BBS, 2020).

In Bangladesh, sunflower is a very minor crop. It has been introduced as an oil seed crop by BARI (Bangladesh Agricultural Research Institute) and MCC (Mennonite Central Committee) reported by (Miah *et al*., 2015). In Bangladesh, sunflower ranks third after mustard and soybeans for oil production. In the cropping (2019-2020) years, sunflower in Bangladesh on 1348 ha of land and the production is 1596 tons (BBS, 2020). While the total area under is 1290 ha with a production of 1975 tons in (2018-19) cropping years (BBS, 2020). According to data provided by the (BBS, 2019), a total of 1540 hectares were used to cultivate sunflowers in Fiscal year of 2020-21, three times higher than the DAE's target of 5,501 hectares for the fiscal year (2019-2020). The (DAE, 2021) data also shows Bangladesh produced 5,725 tons of sunflower seeds in the fiscal year 2020-21, which was 3,052 tons in the previous year (2019-2020). Bangladesh produces 0.358 million tons of edible oil against the annual demand of 1.6 million tons, while the remaining 1.242 million tons of the country's domestic requirements are fulfilled through imports (Khatun *et al*., 2016). More than 90 percent of Bangladesh's demand for sunflower oil is met through imports as a finished product and Bangladesh mainly imports sunflower oil from Turkey, Malaysia, Italy and Ukraine, and other countries, said traders.

Sunflower is an annual erect, broadleaf oilseed crop with a strong tap root system. It is a thermo- neutral crop, therefore can be grown throughout Bangladesh both in rabi and kharif seasons. Sunflower is a short duration crop, which is grown always between Aman and Boro rice in Bangladesh. It can be cultivated in drought, limited water area, even in Barind tract due to its wide adaptability, high yield potential, soil requirement, suitability to mechanization, low labour needs, shorter duration, profitability, high protein (36%), 20-22% carbohydrates, and oil contents (45-52%). requires less irrigation than other oilseed crops reported by (Islam *et al.,* 2019). It can grow in wide ranges of soil types from sand to clay along with a pH of (5.7-8). It can tolerate approximately a (2-12) ds m^{-1} threshold of salinity. In Bangladesh condition, sunflower can be grown in areas of late rainfall or flooded areas where mustard or sesame is not possible to grow.

In sunflower, extracted (48 - 53%) oil is used for edible purposes and the rest non-edible is used for industrial purposes while it characterizes a high proportion of essential unsaturated fatty acids 90 % (Rasool e*t al.,* 2021). Approximately, 500-600 grams of oil is obtained from one kg of sunflower seed which is significantly higher than any other oilseeds. Sunflower oil is generally considered a premium oil because of its light color, high level of unsaturated fatty acids and lack of linolenic acid, bland flavor, and high smoke points. The primary fatty acids in the oil are oleic and linoleic (typically 90% and 18 unsaturated fatty acids), with the remainder consisting of palmitic and stearic saturated fatty acids.

However, the production of sunflower is still below the current needs, all over the world (Muhsin *et al*., 2021) because current soil management strategies are mainly dependent on inorganic chemical-based fertilizers, which caused a serious threat to human health and the environment. Sunflower crops have poor productivity in some areas of Bangladesh, due to the use of low-capacity conventional varieties and the lack of suitable practices such as mineral nutrition and fertilizer management, and sufficient depth of tillage (Muhsin *et al.*, 2021). The poor content of nitrogen and phosphorus characterizes much of the soils in Bangladesh. The use of high doses of chemical fertilizers usually offsets the deficiency that considered an economically and environmentally unsatisfactory solution. For these reasons, there has been an increase in the search for alternate fertilizer sources, which are less environmentally damaging and economically effective. Vermicompost, biochar, and farm yard manure can be a good source of organic farming for sunflower growth and production in Bangladesh.

The exploitation of beneficial microbes as an organic fertilizer has become of paramount importance in the agriculture sector for their potential role in food safety and sustainable crop production (Bhardwaj *et al.*, 2014). Organic manures play a vital role in the physical, chemical, and biological conditions of soil and supply macro and micronutrients to crops, besides maintaining humid substances in soil (Bhardwaj *et al*., 2014). Organic farming is considered a remedy to cure the ills of modern chemical agriculture. It is essential to develop a strong workable, compatible package of nutrient management through organic resources for various crops, capable of providing all the essential minerals for promoting growth. Organic fertilizers have attracted greater attention as a substitute for costly chemical fertilizers. Organic fertilizers provide eco-friendly organic agro-input and are more cost-effective than chemical fertilizers (Amutha *et al*., 2014). Vermicomposting is being used increasingly as plant growth media and soil amendments. In vermicompost, mostly high-density earthworm populations (Sharma *et al.*, 2008) achieve accelerated bio-oxidation of organic matter.

The significance of farmyard manure is being realized again because of the high cost of commercial fertilizers and its long-term adverse effect on soil chemical properties. Besides supplying macronutrients and micronutrients to the soil, fertility of the soil improved by using farmyard manure (Hossain & Akter, 2020). There are enough places to replenish the soil by utilizing available sources, such as natural and organic fertilizers. Numerous researchers conducted various experiments to evaluate the impact of organic fertilizers application on sunflower instead of chemical fertilizers.

The need for bio-energy is increasing with the increase in global energy demand, sustainable soil and fertilizer management practices are gaining importance. Biochar is a solid, carbon rich material made by chemical-thermal conversion of biomass in an environment with a shortage or absence of oxygen (Salmani *et al.*, 2014). Research has shown that adding biochar to the soil increases soil fertility and agricultural productivity significantly (Rondon *et al.*, 2009). Treatment with 1% and 2% biochar in medium and high copper toxicity levels prevented significant decrease in sunflower growth. Plant height, quality (chlorophyll content), biomass yield, feedstock energy, ash content, and tissue nutrients were increased along with soil moisture and pH for sunflower by applying biochar (Saha *et al*., 2016). Therefore, we can boost the production of sunflower by expanding the proper applying of organic and bio-fertilizer. Hence, sunflower would not only meet the acute shortage of edible oil but could be a great promising crop, especially in the context of climate change in Bangladesh. For higher productivity and sustainability, integrated use of organic and biofertilizer as a source of nutrients is very important. Keeping these aspects in view, the present investigation was carried out

i. To study the growth and yield performance of sunflower (*Helianthus annuus* L.) with different organic fertilizer treatments.
ii. To find out the appropriate treatment combination of organic fertilizer for improving the sunflower yield.

CHAPTER II

REVIEW OF LITERATURE

This chapter has been made to review the available information in home and abroad regarding the study on effect of organic treatments on growth and yield of sunflower (*Helianthus annuus* L.) Organic fertilizer bears great significance on soil productivity. The organic fertilizers like FYM, vermicompost, Biochar, compost, cow dung, poultry manure, green manure, compost etc. Organic fertilizers added organic nutrients to the soil and gives the long-lasting effect on soil. It increases the soil health condition and chemical free. An attempt was made in the section and the study relevant information available regarding the use of organic fertilizers on sunflower production of the present research work and findings would come out from the experimentation.

2.1 Plant height

Gül *et al*. (2021) reported that vermicompost is not harmful to the environment and increases agricultural production in terms of both gaining to the soil and benefiting the waste. This research was carried out in 2019 in Bayburt ecological conditions in order to determine the impacts of different doses of solid (250, 500, and 750 kg ha^{-1}) and liquid (0, 250, 500, and 750 ml ha^{-1}) vermicompost fertilizers on the flowering and maturation period (days), stem diameter (cm), table diameter (cm), plant height (cm), thousand weight (g) seed yield (kg ha^{-1}), seed internal rate (%) oil ratio (%) and oil yield (kg ha^{-1}) of sunflower (*Helianthus annuus*). In the experiment, it was determined that all parameters were statistically significant compared top<0.01. Therefore, the treatment K_0S_2that means solid vermicompost (0 kg) and liquid vermicompost (500 ml) showed the highest plant height (117.9 cm). The highest seed (218.7 kg ha^{-1}) and oil yield (75.9 kg ha^{-1}), which are the most important parameters in oil sunflower, were obtained in 750 kg ha^{-1} solid and 750 ml ha^{-1} liquid vermicompost application (K3S3). As a result, the use of solid and liquid vermicompost application in oil sunflower together will be beneficial in obtaining the highest healthy, high-quality seed and oil yield.

Contaminated soils can cause a potential risk to the health of the environment and soil as well as the quality and productivity of plants. The objectives of the research were to investigate the integrative advantageous effects of foliar ZnO nanoparticles (NPs) (60 mg Zn NPs L^{-1}), rice straw biochar (RSB; 8.0 t ha^{-1}), Cow-manure biochar (CMB, 8.0 t ha^{-1}), and a combination thereof (50% of each) on sunflowers grown in agricultural land irrigated with polluted wastewater for the long term (≈50 years). The availability of heavy metals (HMs) in soil, HMs accumulation in whole biomass aboveground, growth, productivity, and quality characteristics of the sunflower was investigated. The combination treatment significantly minimized the availability of HMs in soil, and, consequently, substantially lessened the uptake of HMs by the sunflower, compared to treatments of ZnO, NPs and control (*i.e.*, untreated soil). The application of the combination treatment reduced the availability of Pb, Cr, Cu, and Cd in the soil by 78.6%, 115.3%, 153.3%, and 178.5% in comparison to untreated plots post-harvest, respectively. Compared to untreated plots, it also reduced the Pb, Cr, Cu, and Cd in plant biomass by 1.13, 5.19, 3.88, and 0.26 mg kg $^{-1}$ DM, respectively. Furthermore, combination treatment followed by biochar as an individual application caused a significant improvement in sunflower productivity and quality in comparison to untreated soil. For instance, seed yield ha^{-1}, 1000-seeds weight, and number of seeds per head obtained from the combination treatment were greater than the results obtained from the untreated plots by 42.6%, 47.0%, and 50.4%, respectively. In summary, the combined treatment of NPs and both RSB and CMB is recommended as a result of their positive influence on sunflower oil quality and yield as well as on minimizing the negative influences of heavy metals (Seleiman *et al*., 2020).

Hossain and Akter (2020) reported a pot experiment was carried out to assess the comparative effects of Trichoderma-enriched biofertilizer and farmyard manure on the growth and yield components of sunflower. The treatments were T_0 (control), T_1 (Trichoderma-enriched biofertilizer 5 t ha^{-1}), T_2 (Trichoderma-enriched biofertilizer 10 t ha^{-1}), T_3 (Trichoderma- enriched biofertilizer 5 t ha^{-1}+ Farm yard manure 5 t ha^{-1}), T_4 (Farm yard manure 5 t ha^{-1}), T_5 (Farm yard manure 10 t ha^{-1}) and T_6 (Farm yard manure 15 t ha^{-1}). Among the different treatments, T_3 showed best as much as twice more effective in increasing growth and yield parameters as for example plant height, leaf length, fresh weight, and dry weight of stem, seed number of plants. Overall, all the treatments increased macronutrients and micronutrients content and uptake by sunflower plants over control. Analysis of post-harvest soil samples also revealed that all the parameters except pH were increased due to different treatments.

Gyewali *et al*. (2020) reported that an experiment was conducted to evaluate the influence of different organic manures on the growth, yield, and quality of sunflower (*Helianthus annus*) at Institute of Agriculture and Animal Science (IAAS), Rupandehi, Nepal. The treatments were consisted as farmyard manure (FYM) (30 t ha^{-1}), poultry manure (PM) (30 t ha^{-1}), FYM (15 t ha^{-1}) + PM (15 t ha^{-1}), FYM (15 t ha^{-1}) + vermin compost (2.5 t ha^{-1}) + phosphate solubilizing bacteria (PSB) (10 kg ha^{-1}), FYM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}). A significant variation was observed among the treatments. The poultry manures combined with bone meal and PSB significantly increased the growth and yield attributes viz., plant height (43.43 cm), number of leaves (20.9), leaf length (21.68 cm), stem diameter (13.77 cm), biological yield (82.28 g $plant^{-1}$), dry weight of seeds (46.89 g $plant^{-1}$), total dry weight (97.22 g $plant^{-1}$), root yield (49.31 t ha^{-1}), yield (939.87 t ha^{-1}) and biological yield (89.19 t ha^{-1}) at 70 days after sowing. However, the total soluble solid remains unchanged among the treatments. In total, the results suggested that poultry manures combined with bone meal and PSB is suitable to cultivate sunflower.

Khan *et al*. (2016) was conducted an experiment to evaluate the influence of different organic manures on growth, yield, and quality of sunflower at Institute of Agriculture and Animal Science (IAAS), Rupandehi, Nepal. The treatments were consisted of farmyard manure (FYM) (30 t ha^{-1}), poultry manure (PM) (30 t ha^{-1}), FYM (15 t ha^{-1}) + PM (15 t ha^{-1}), FYM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + phosphate solubilizing bacteria (PSB) (10 $kgha^{-1}$), FYM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + PSB (10 $kgha^{-1}$), PM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}). Result showed that the poultry manures combined with bone meal and PSB significantly increased the growth and yield attributes viz., plant height (40.43 cm), number of leaves (18.9), stem diameter (3.77 cm), seed fresh weight (211.3 g $plant^{-1}$), biological yield (82.28 g $plant^{-1}$), dry seed weight (46.89 g $plant^{-1}$), total dry weight (97.22 g $plant^{-1}$), seed yield (49.31 t ha^{-1}), head yield (939.87 t ha^{-1}) and biological yield (89.19 t ha^{-1}) at 70 days after sowing. However, the total soluble solid remains unchanged among the treatments. In total, the results suggested that poultry manures combined with bone meal and PSB is suitable to cultivate sunflower.

Two field experiments were conducted on the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta in south western Nigeria to evaluate the performance of two sunflower varieties (SAMSUN-3 and Funtua) as affected by different sowing dates and organic fertilizer application. Sowing date significantly (P = 0.05) increased and reduced number of phenological days to flowering of early and late sown sunflower, respectively. Application of organic fertilizer significantly (P = 0.05) increased plant height of early and late sown sunflower. Delay in sowing till first week in September significantly (P= 0.05) reduced head diameter, number of seeds per head and seed yield of late sown sunflower. Oil and protein contents of seeds from early and late sown sunflower plants were significantly (P= 0.05) increased by organic fertilizer application, except protein content of late sown sunflower. However, it significantly (P = 0.05) increased oil yield by 23% relative to the control in the late sown sunflower. Based on the comparatively high seed yield (850.45–1,525.78 kg ha^{-1} recorded that sunflower be sown in the forest–savanna transition zone in early July or second to third week in August (Oshundiya *et al*., 2014).

Kumar *et al*. (2018) reported the effects of organic amendments on plant height of mustard presented significant difference values of plant height with application of different organic amendments during both the years. It was found that at 30 DAS the application of vermicompost @ 5 ton ha^{-1} (T_{16}) recorded significantly highest plant height 28.36 cm and 27.56 cm of mustard in 2015-16 and 2016-17, respectively. At 60 DAS and 90 DAS the application of 20 ppm chromium + vermicompost @ 5 t ha^{-1} (T_{17}) recorded highest plant height 99.13 cm and 98.95 cm of mustard in 2015- 16 and 2016-17, respectively. At 90 DAS also the application of 20 ppm chromium + vermicompost @ 5 ton ha^{-1} (T_{17}) recorded highest plant height 164.93cm and 168.10 cm of mustard in 2015-16 and 2016-17, respectively. At Harvest the application of 40 ppm chromium + vermicompost @ 5ton ha^{-1} (T_{18}) recorded significantly highest plant height 179.56 and 178.79 cm of mustard in 2015-16 and 2016-17 respectively.

Keshta *et al*. (2008) reported that the tallest plant (236 cm) was recorded with the higher FYM application (T_4 treatment) followed by T_5 treatment and the shortest plants were obtained with T_7. On the other hand, at El-Serw site (S_2), it was found that, with the exception of T_2 treatment, plant height was significantly less under all fertilization treatments than under the control (T_1) treatment. Data also revealed that the number of leaves $plant^{-1}$ was significantly affected by all treatments at site S_1 only. The highest and lowest values were observed with T_4 and T_7, respectively, while, there was no significant effect at El-Serw site (S_2).

2.2. Stem diameter

Seleiman *et al*. (2020) reported to investigate the integrative advantageous effects of foliar Zn nanoparticles (NPs) (60 mg Zn NPs L^{-1}), rice straw biochar (RSB; 8.0 t ha^{-1}), cow-manure biochar (CMB, 8.0 t ha^{-1}), and a combination thereof (50% of each) on sunflowers grown in agricultural land irrigated with polluted wastewater for the long term (≈50 years). The combination treatment significantly minimized the availability of HMs in soil, and, consequently, substantially lessened the uptake of HMs by the sunflower, compared to treatments of ZnO NPs and control (i.e., untreated soil). The application of the combination treatment reduced the availability of Pb, Cr, Cu, and Cd in the soil by 78.6%, 115.3%, 153.3%, and 178.5% in comparison to untreated plots post-harvest, respectively. Compared to untreated plots, it also reduced the Pb, Cr, Cu, and Cd in plant biomass by 1.13, 5.19, 3.88, and 0.26 mg kg^{-1} DM, respectively. Furthermore, combination treatment followed by biochar as an individual application caused a significant improvement in sunflower productivity and quality in comparison to untreated soil. For instance, stem diameter, seed yield ha^{-1}, 1000-seed weight, and number of seeds per head obtained from the combination treatment was greater than the results obtained from the untreated plots by 42.6%, 47.0%, and 50.4%, respectively. In summary, the combined treatment of NPs and both RSB and CMB is recommended as a result of their positive influence on sunflower oil quality and yield as well as on minimizing the negative influences of HMs.

Gül *et al*. (2021) reported that vermicompost, which is not harmful to the environment, and is increasing in agricultural production in terms of both gaining to the soil and benefiting the waste. This research was carried out in 2019 in Bayburt ecological conditions in order to determine the impacts of different doses of solid (250, 500 and 750 kg ha^{-1}) and liquid (0, 250, 500 and 750 ml ha^{-1}) vermicompost fertilizers on the flowering and maturation period (days), stem diameter (cm), table diameter (cm), plant height (cm), thousand weight (g) seed yield (kg ha^{-1}), seed internal rate (%), oil ratio (%) and oil yield (kg ha^{-1}) of sunflower (*Helianthus annuus*). In the experiment, it was determined that all parameters were statistically significant compared to $p<0.01$. The highest seed (218.7 kg ha^{-1}) and oil yield (75.9 kg ha^{-1}), which are the most important parameters in oil sunflower, were obtained in 750 kg da^{-1} solid and 750 ml ha^{-1} Liquid vermicompost application (K3S3). As a result, the use of solid and liquid vermicompost application in oil sunflower together will be beneficial in obtaining the highest healthy, high-quality seed and oil yield.

Vedpathak and Chavan (2016) conducted an experiment to study on impact of organic on growth and yield components of Sunflower crop on season. A common dose of organic fertilizers such as Vermicompost (T_1), NADEP compost (T_2) and pit compost (T_3) were used at equal rate 1.25 kg $plot^{-1}$ (@ 0.625 kg sq. m^{-1}). Chemical fertilizers (T_4) were used as stated by recommended dose of fertilizers (60:30:30- N: P2O5: K2O Kg ha^{-1}). Not any fertilizers were added in treatment (T_5) that is to be named as control. NADEP compost treatment (T_2) increases maximum plant height (110.8cm plant^{-1}). It was 107.9 cm plant^{-1} with application of pit compost treatment (T_3) and lower plant height 98.65 cm plant^{-1} was observed with application of chemical fertilizers (T_4) after 90th day. The maximum (6.38 cm plant^{-1}), minimum (5.90 cm plant^{-1}) and lower (4.85 cm plant^{-1}) of head diameter of sunflower plant were observed with application of NADEP compost treatment (T_2), vermicompost treatment (T_1) and control field treatment (T_5) respectively after 90th day. The highest mean weight of seeds head^{-1} (5.97g head^{-1}) was recorded in vermicompost treatment (T_{10}) followed by NADEP compost treatment (5.42g head^{-1}). The lowest weight of seeds head^{-1} (1.70 g head^{-1}) in pit compost treatment T_3. The maximum dry weight of 100 seeds of sunflower crop (2.64g plant^{-1}) was recorded in vermicompost treatment T1 followed in order by treatment T_2 (2.34g plant^{-1}), treatment T_4 (2.28g plant^{-1}), treatment T_3 (1.99g plant^{-1}) and treatment T_5 (1.96g plant^{-1}). The maximum yield of Sunflower crop (0.089 Kg plot^{-1}) was achieved in vermicompost treatment (T_1) which was more than remaining fertilizer treatments and lower yield is 00.026 Kg plot^{-1} was recorded in plot treated with pit compost treatment (T_3). It was concluded that, the application of vermicompost increases yield of sunflower crop followed by in order NADEP compost, pit compost, chemical fertilizers and control. Therefore, it can be showed that use of organic fertilizers in agricultural field give progressive response compared to chemical fertilizers for sunflower production.

2.3. Leaves number plant^{-1}

Application of organic amendments significantly influenced sunflower number of leaves plant^{-1} in Cr contaminated soil during both the years. During 2015-16 number of leaves per plant varied from 9.00 to 5.55, 18.67 to 11.00, 65.78 to 30.78 and 56.22 to 26.89 at 30, 60, 90 DAS and at harvest, respectively while during 2016-17 it varied from 9.22 to 5.56, 20.22 to 11.22, 67.89 to 33.22 and 56.44 to 27.11 at 30, 60, 90 DAS and at harvest, respectively (Kumar *et al*., 2018).

Khan *et al*. (2016) reported that at harvest, the leaves number of sunflower was observed maximum in T_2 being, 63.77 plant^{-1} and 63.14 plant^{-1} for the 1st and 2nd year, respectively. The effect of organic manure levels on plant leaves number was significant at the both locations. Plant leaves number values at M_3 and M_2 organic manure levels were higher than those at control treatment without organic manure. Also, Palacio-Román *et al*. (2020) mentioned that application of manure had significant effect on the number of leaves for sunflower.

2.4. Leaf area of sunflower

Effects of Rice straw biochar (RSB) and Cow manure biochar (CMB) on leaf area of sunflowers grown in long-term contaminated soil are illustrated. The greatest leaf area per plant and proline content of sunflower grown in polluted soil was obtained from plots given the combination treatment. **(**Seleiman *et al*., 2020). A significant increase in growth is well demonstrated due to application of vermicompost and biogas slurry under non saline soil expressed in terms of plant leaf area (Ahmad & Jabeen, 2009).

The amount of organic manure has significant effect on the leaf area (Table 4). M_3 gave wider leaves (3689.55 cm^2, and2778.94 cm^2) $plant^{-1}$ in the SL and QL location respectively) than that of control without organic manure (2049.94 55 cm^2 and 1973.55 cm^2) $plant^{-1}$ in the SL and QL location respectively (Muhsin *et al*., 2021).

Leaf area, specific leaf area (SLA) showed significant differences between treatments with biochar as a whole with respect to the control, and depending on the biochar type. The SLA was higher in plants grown with biochar compared to control plants (Fig. 3e), with the exception of those from WSB (Wheat-straw biochar) treatment, which showed a lower SLA (especially at high application rates). Leaf-area ratio (LAR), which indicates the leaf area relative to plant biomass, was higher in biochar-treated soils, with all the biochar samples showing a similar trend (Alburquerque *et al*., 2014).

2.5. Dry weight of sunflower

Rasool *et al*. (2013) reported that a field experiment was conducted at the Research farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, India for two consecutive rainy (kharif) seasons of 2009 and 2010 to find out the impact of nitrogen, sulphur and farmyard manure (FYM) on growth and yield of sunflower (*Helianthus annuus* L.). 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 decreased but the oil yield improved during both years. Sulphur application at the rate of 60 kg ha^{-1} significantly increased 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 higher with 60 kg S ha^{-1} over 30 kg S ha^{-1}. Seed and stalk yield with 60 kg S ha^{-1} were significantly higher than those of 30 kg S ha^{-1}. Similarly, oil content and oil yield with 60kg 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 recorded 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.

Dambale *et al*. (2018) reported that dry matter per plant (g) amongst the various plant parts as affected by various treatments. The application of 100 % RDF + FYM @ 5 t ha^{-1} (T_2) recorded significantly higher total dry matter per plant at harvest i.e 132.67 respectively of sunflower which was at per with application the of 100 % RDF + SR @ 5 t ha-1 (T1), 100 % RDF + FYM @ 5 t ha^{-1} (T_3) and was found significantly superior over the rest of the treatments significantly superior over the rest of treatments.

2.6. Chlorophyll content of sunflower

Alzamel *et al.* (2022) reported that sunflower is the most important source of edible oil and fourth-largest oilseed crop in the world. The purpose of this study was to investigate the effect of using two organic fertilizers from various sources (compost coupled with bio fertilizer (CCB), filter mud cake (FMC)) and comparing them to conventional inorganic fertilizers in their effect on the quality of sunflower seeds, sunflower oil, and soil properties. The data showed that the highest value of dry weight, plant height, disk dry weight in addition to chlorophyll content, and phenolic secondary metabolites in oil was measured after the application of inorganic fertilizer, while the use of organic fertilizer contributed to a substantial increase in the production yield of sunflower seeds, oil, and a high stalk yield compared with inorganic treatment. Oils produced from organic fertilizer (CCB and FMC) gave higher blue color values than inorganic ones and the most transparent oil was inorganic while the organic treatments produced darkest oils. The results for chemical composition of sunflower seeds showed nonsignificant differences for protein and ash among all treatments while a significant difference with regard to oil content was recorded, in which the FMC recorded the highest oil content followed by compost (CCB), and finally came the inorganic treatment. Organic fertilizers are a valuable source of organic material and nutrients essential for plants and can be safely used for soil, crops, and the environment. The highest sunflower chlorophyll content at all sampling dates was obtained when the combination treatment was applied compared to untreated soil. This was followed by applications of RSB = Rice straw biochar, CMB = Cow manure biochar, CMB, RSB, and Zn NPs. Compared to the untreated soil, the application of a combination treatment (i.e., CMB + RSB + Zn NPs) increased the total chlorophyll content by 26.6%, 29.9%, 27.4%, and 35.6% at 25, 45, 65, and 85 DAS, respectively (Seleiman *et al*., 2020).

Jabborova *et al.* (2021) reported that the effect of biochar on lettuce using biochar additions of 1%, 2% and 3% in a pot experiment. The plant parameters assessed under greenhouse conditions were the germination rate, leaf length, leaf number, leaf width as well as fresh root weight, fresh shoot weight, dry root weight, dry shoot weight, and root morphological traits. Both biochar 2% and biochar 3% treatments significantly improved lettuce growth (leaf length, leaf number, leaf width) compared with the control, while no significant differences were observed in the biochar 1% treatment. However, biochar 3% treatment significantly enhanced the root morphological traits such as total root length, the root surface area, the projected area and the root volume compared to the control. The total chlorophyll content and carotenoid content improved with increasing levels of biochar 3% treatment, which significantly increased by 43% and 51% compared with the control. The highest acid phosphor monoestrase activities were seen with the application of biochar 3%, which was 19% and 31% higher than that of the biochar 1% and control treatments, respectively. Moreover, a significant increase in soil enzyme activities (fluorescein diacetate hydrolase, acid and alkaline phosphor monoestrase) was observed with the biochar 2% and biochar 3% treatments compared to the control. This study indicated that biochar could promote lettuce growth and enhance soil enzyme activities.

2.7. Head diameter of sunflower

Gül *et al*. (2021) reported that the effects of different doses of solid and liquid vermicompost applied to sunflower it showed significant variation on head diameter. In treatment K_3S_1 means solid Vermicompost K_3 (750 kg) and liquid Vermicompost S_1 (250 ml) showed the maximum head diameter (15.6 cm). A significant increase in growth is well demonstrated due to application of vermicompost and biogas slurry under non saline soil expressed in terms of plant disc diameter (Ahmad *et al.*, 2009).

Abd-Elhamied *et al.* (2018) studied that head diameter increased significantly sunflower head diameter (cm) compared with control treatment. In addition, adding poultry manure increased head diameter (cm) compared with adding biochar. The head diameter of sunflower plant at harvest time 120 days from planting were improved significantly with increasing compost rates up to 4 t fed^{-1} compared without compost addition in both seasons, reached by 37.07 for 1st season and 37.68 for 2nd season respectively.

The application of organic manure in the first cropping season produced the highest head diameter compared to that of the second cropping season for all treatments. Both cropping season and organic manure had a significant effect on head diameter. Organic manure contributed to a significant increase in head diameter over the control in the second cropping season compared to the first cropping season, supporting the findings of (Wabekwa *et al*., 2014).

2.8. Seed number head^{-1} of sunflower

The application of a single CMB and RSB increased the number of seeds per head of sunflower by 40.0% and 26.6% respectively (Seleiman *et al*., 2020). The number of seeds per flower was obtained by random selection of flowers from each treatment. Maximum number per flower was obtained from treatment T_1 (Organic manure + Biofertilizer, VAM). Statistical analysis revealed that all the treatments recorded significantly higher number over control (Khodaei-joghan *et al*., 2018).

Akbari *et al*. (2011) conducted an experiment to study the effect of organic, chemical and integrated nutritional levels and Plant Growth Promoting Rhizobacteria (PGPR) on the grain yield and quality traits of sunflower (Helianthus annuus L.). A total of five nutritional levels, including 100% organic (F1), 25% chemical and 75% organic (F2), 50% chemical and 50% organic (F3), 75% chemical and 25% organic (F4) and 100% chemical (F5), were utilised in the main plot, and two levels of PGPR inoculation (I0, I1) were established in sub-plots, respectively. The treatments were arranged in a split-plot design based on RCB with three replications. 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 superior in the F3, F4, and F2 integrated nutritional levels compared to the completely organic (F1) and chemical levels (F5). In the F3 integrated level, the total increased seed yield (2924.9) was approximately 40% of the lowest seed yield for the F1 level (1777.1). According to the results for the yield, the order was F3>F4>F2>F5>F1 respectively. The highest and lowest contents of oil were observed in the F1 level (51.07) and F3 level (49.35), respectively. The results showed that inoculating the seeds with PGPR increased the qualitative and quantitative properties of sunflower significantly, as compared to the control treatment.

Muhsin *et al*. (2021) reported that there was significant difference between organic manure levels, on the number of seed per head in sunflower. The maximum number of seed per head (1383.67 and 1379.33 seeds head^{-1} in the SL and QL location respectively was recorded in the treatment of M_3 (organic manure 10 t ha^{-1}). Minimum seed per head (1331.78 and 1328.33 seeds head^{-1} in the SL and QL location respectively) was found in the treatment of M_0 (without manure fertilizer control).

2.9. Weight of seed per head of sunflower

The application of organic manure under salinity increased the number and weight of seeds per floral disc, which resulted in an increase in seed yield and oil content per floral disc of sunflower (Ahmad and Jabeen., 2009). Alzamel *et al*. (2022) reported that compost (CCB) treatment recorded the second highest level of disk dry weight after inorganic treatment. This significant difference between treatments may be due to solubility that is more nutrient in mineral form in inorganic treatment than other treatments, which increased plant nutrient uptake. There was a significant effect ($p<0.05$) on head dry matter in both cropping seasons. Poultry manure (49.27 g head^{-1}) and the combined manure (32.50 g head^{-1}) produced the highest head dry matter values in the first and second cropping seasons, respectively reported by (Mokgolo *et al*., 2019).

2.10. Thousand seed weight of sunflower

Application of biofertilizer along with VAM without sulphur produced significantly highest 1000 seed weight in T_4 followed by T_1 and T_3 Minimum seed index i.e.2.60 g for 2013-14 and 2.65 g for 2014- 15 was found for the treatment with 100% chemical and untreated control. Treatment T_4, T_3 and T_1 were significantly higher than untreated control (Khan *et al*., 2016).

Soleymani *et al*. (2016) reported that combined treatment of vermicompost and half of recommended chemical fertilizer yielded maximum 1000- seed weight (56.67 g). 1000 seed weight and seed yield (kg fed^{-1}) of sunflower plant at harvest time 120 days from planting were improved significantly with increasing compost rates up to 4 t fed^{-1} compared without compost addition in both seasons, reached by 58.06 for 1st season and 29.88 for 2nd season respectively.

2.11. Stover yield of sunflower

De Jesus *et al.* (2020) reported that effects of annual organic fertilization on maize and sunflower yields and on physical and chemical characteristics of Fluvisol were evaluated in the semiarid area of Paraiba state, from 2007 to 2011. Grain and stover yields increased with fertilization, especially in the years of good rains (maize, 0–61%, reaching 3.4 Mg ha^{-1} of grain; sunflower, 48–112%, reaching 1.4 Mg ha^{-1} of achenes), differing only slightly between fertilizer types and form of application. All fertilizers incorporated for 5 years reduced water infiltration time (20–50%), but only manure and *G. sepium* reduced soil bulk density (about 10%) and increased soil porosity (7–10%). Manure increased soil pH (0.7–1.0 units). Surface application of manure and *C. sonderianus* increased soil organic matter (28 and 72%) and phosphorus concentrations (about 70%). We suggest that, in sites with soil physical problems (slow water infiltration, high soil compaction, and low porosity), organic fertilizers may lead to better responses if incorporated into the soil. If there is a need for greater improvement of soil organic matter, nutrients and water conservation, surface applied organic manure and *C. sonderianus* may be a better management practice.

2.12. Seed yield of sunflower

A field experiment was conducted, during two growing seasons, under open field conditions at Agricultural Research Center, Egypt. The study aimed to determine the effect of different irrigation water levels (60, 80 and 100% of crop evapotranspiration (ETc)) and fertilization (mineral fertilizers (control), farm yard manure (FYM), biochar, compost and vermi-compost) on growth, yield, water use efficiency and nutritional status of lettuce (*Lactuca sativa* L.). Applying different irrigation water levels and fertilizers significantly affected the vegetative growth and yield traits, i.e., no. of leaves, weight, head length and width, and total chlorophyll, as well as nutrient contents (N, P, and K) and total soluble solids (TSS). Data revealed that using vermicompost fertilizer reduced irrigation water requirements of lettuce plants, compared with control treatment. Also, vermicompost treatment gave the highest values of the studied plant traits, during the two tested seasons. Increasing irrigation level up to 80% of ET enhanced the yield, with additions of organic fertilizer treatments, and increased water use efficiency. Moreover, the treatment of vermicompost + 80% of ETc gave the highest benefit-cost ratio (BCR values were 3.08 and 2.77 during the two tested seasons, respectively), while the lowest ones (0.85 and 0.93) were recorded by applying the treatment of mineral fertilizers+ 60% of ETc during the two studied seasons respectively. The significant main effect of fertilization treatments showed that vermicompost and biochar caused increase in lettuce yield like that of mineral fertilizer reported by (Abd–Elhamied *et al*., 2022).

Alzamel *et al*. (2022) reported the results in the compost (CCB) treatment scored the highest seed yield (8.963), highest oil yield (3.988), and highest stalk yield (11.795), followed by filter mud cake (7.387, 3.625, and 10.01, respectively), while inorganic treatment recorded the lowest values (6.60, 2.626, and 9.390, respectively).

It was observed that both solid and liquid vermicompost application increases the efficiency more than only solid vermicompost application. According to the given results, the highest seed yield (218.7 kg da^{-1}) was obtained from the treatment vermicompost application studied by (Gül *et al*., 2021). In case of sunflower crop production, manure application in the second season resulted in an increase in the seed yield compared to the first season, except after application of poultry manure where after the seed yield decreased significantly by 168% from the first cropping season (Mokgolo *et al*., 2019).

In the case of sunflower seed yield $plant^{-1}$, the individual application of CCD slightly increased this up to 44, 55, and 74% at 1.8, 6, and 12 dS m^{-1} respectively, compared with the control (Naveed *et al*., 2021). Application of organic fertilizer significantly ($P \leq 0.05$; F-test) increased seed yield, all yield attributes, oil yield and seed quality of late sown sunflower, except protein content reported by (Oshundiya *et al*., 2014)

The seed yield $plant^{-1}$ and seed yield (kg fed^{-1}) of sunflower plant at harvest time 120 days from planting were improved significantly with increasing compost rates up to 4 t fed^{-1} compared without compost addition in both seasons, reached by 28.45, and 37.24% for 1st season and 54.88 and 32.86 % for 2nd season, respectively. This increment in sunflower seed yield may be due to the increase in 1000-seed weight reported by EAM *et al*. (2014).

Rasool *et al*. (2013) reported that significant increase in yield components and seed yield was observed with application of farmyard manure, which helped better crop growth, produced better yield attributes, and ultimately higher seed yield during both the years. Application of 10 and 20 t ha^{-1} of farmyard manure increased seed yield by 9 and 15%, respectively over no application.

Thind *et al*. (2007) studied that organic manures had significant residual effect on seed yield, growth and phenology of sunflower, the response to VC and BC being more than green manures. Combination of BC with VC application up to 60 kg ha^{-1} to sunflower also improved seed yield.

2.13. Biological yield

Gyewali *et al*. (2020) conducted an experiment to evaluate the influence of different organic manures on growth, yield, and quality of sunflower at Institute of Agriculture and Animal Science (IAAS), Rupandehi, Nepal. The treatments were consisted as farmyard manure (FYM) (30 tha^{-1}), poultry manure (PM) (30 t ha^{-1}), FYM(15 t ha^{-1}) + PM (15 t ha^{-1}), FYM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + phosphate solubilizing bacteria (PSB) (10 kg ha^{-1}), FYM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}). The fram yard manures combined with bone meal and PSB significantly increased the growth and yield attributes viz., plant height (43.43 cm), number of leaves (20.9), shoot length (44.49 cm), root length (21.68 cm), root diameter (3.77 cm), root weight (211.3 g plant^{-1}), shoot weight (170.9 g plant^{-1}), biological yield (82.28 g plant^{-1}), dry root weight (46.89 g plant^{-1}), dry shoot weight (50.33 g plant^{-1}), total dry weight (97.22 g plant^{-1}), root yield (49.31 t ha^{-1}), shoot yield (939.87 t ha^{-1}) and biological yield (89.19 t ha^{-1}) at 70 days after sowing. In total, the results suggested that farm yard manures combined with bone meal and PSB is suitable to cultivate sunflower.

Munir *et al*. (2007) reported that the incorporation of inorganic and organic fertilizers resulted in a maximum biological yield of sunflower and it might be because of the nutrients availability and enhanced nutrient uptake which leads to the higher biological yield.

Saeed *et al*. (2002) stated that organic manure alone or in combination with synthetic fertilizers significantly, increased grain and biological yield against control for sunflower the significant main effect of fertilization treatments showed that vermicompost and biochar caused increase sunflower yield like that of mineral fertilizer (Abd–Elrahman *et al*., 2022)

2.14. Harvest index

Abd-Elrahman *et al*. (2021) was conducted a field experiment during two growing seasons, under open field conditions at Agricultural Research Center, Egypt. The study aimed to determine the effect of different irrigation water levels (60, 80 and 100% of crop evapotranspiration (ETc)) and fertilization *i.e.,* mineral fertilizers (control), farmyard manure (FYM), biochar, compost, and vermicompost) on growth, yield, water use efficiency and nutritional status of sunflower (*Helianthus annuus* L.). Data revealed that using vermicompost fertilizer reduced irrigation water requirements of sunflower plants, compared with control treatment. In addition, vermicompost treatment gave the highest values of the studied plant traits, during the two tested seasons. Increasing irrigation level up to 80% of ETc enhanced the yield, with additions of organic fertilizer treatments, and increased water use efficiency. Moreover, the treatment of vermicompost + 80% of ETc gave the highest benefit-cost ratio (BCR values were 3.08 and 2.77 during the two tested seasons, respectively), while the lowest ones (0.85 and 0.93) were recorded by applying the treatment of mineral fertilizers+ 60% off.

2.15. Water holding capacity

Yu *et al*. (2018) studied to determine the effect of woody biochar amendment (yellow pine from pyrolysis at 400°C) on the water holding capacity of loamy sand soil with different mixture rates. Results show a doubling in water holding capacity by mass using a 9% mixture of biochar (equivalent to 195 metric ton/ha), which is an agriculturally relevant concentration. High percentage mixtures of biochar increase water holding capacity dramatically. These results suggest the use of biochar has potential to mitigate drought and increase crop yields in loamy sand soil.

Gondim *et al.* (2018) reported that two species from caatinga biome were used, jurema-preta (Mimosa tenuiflora Willd. Poir.) and marmeleiro (Croton sonderianus Müll. Arg.). This study aimed to identify the best biochar material regionally available to increase water-holding capacity in the soil, based on laboratory tests and microstructural porosity evaluation. Biochar from Caatinga wood demonstrated an improved water holding capacity if compared to cashew wood biochar. The particle diameters of 2 and 4 mm showed the highest levels, which were 2,268 gg^{-1} for caatinga wood and $0.574g^{-1}$ for cashew wood biochars, respectively. While the smaller quantities of macropores and a larger number of micropores (smaller radius) could explain the higher water-holding capacity for biochar from caatinga wood, the thick lignified cell walls of biochar from cashew wood support the idea of a hydrophobic effect contributing to water lower holding capacity.

CHAPTER III

MATERIALS AND METHODS

This chapter briefly describes the materials and methods that are used in performing the research work. The chapter is presented under the following heads: location, soil characteristics climatic condition, properties of material, treatments of the experiment, land preparation, experimental design, layout of the experimental plots, fertilizer application, sowing of the seeds in the field, intercultural operations, harvesting and threshing, data collection and statistical analysis.

3.1 Geographical location of the experimental site

The experiment was conducted in the Agronomy Research Field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh from November 2021 to April 2022. The geographical position of the experimental area and location is between $25^{0}44.574^{//}$N and $88^{o}40.344^{//}$E and 40 m above sea level shown in (Figure 1a and 1b).

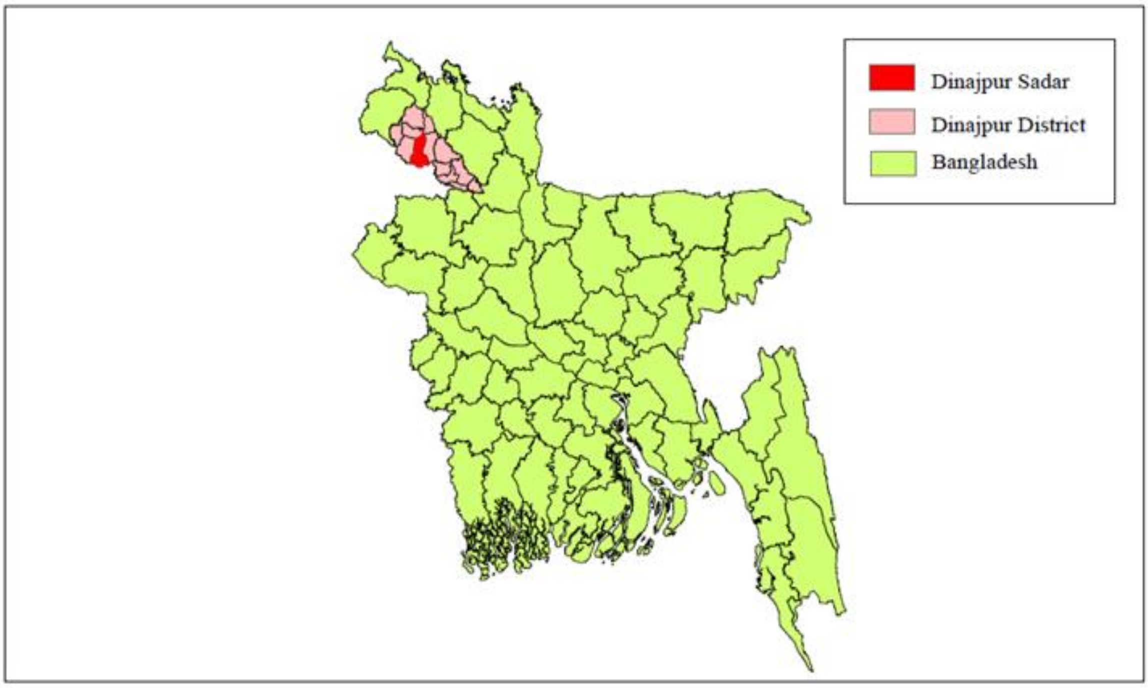


Figure: 1 (a) Location of the experimental area

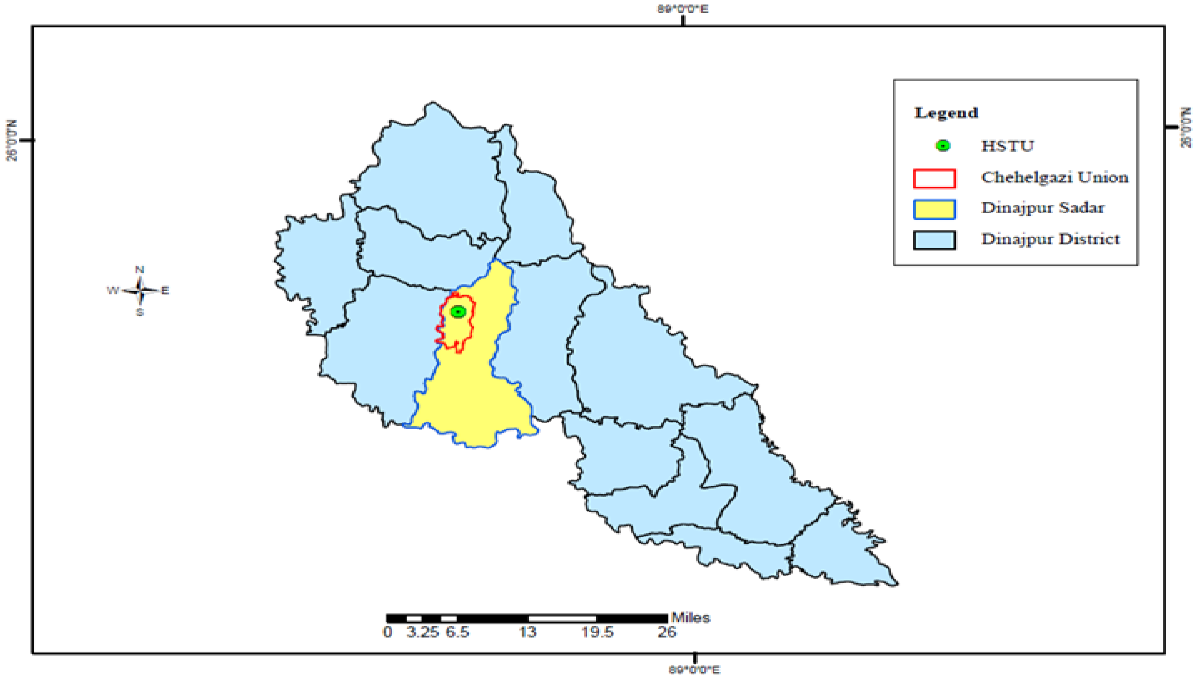


Figure 1(b): Location of experimental fie

3.2 Climatic conditions

The climate was subtropical with low temperatures and minimum rainfall from December to April which is the main feature of the Rabi season. The highest maximum temperature was shown in the month of April *i.e.*, 35.0^{0}C. The lowest maximum temperature was shown in January at 24.0^{0}C. While the highest minimum temperature was recorded in the month of April at 18.0^{0}C and the lowest in the month of December at 13.0^{0}C shown in (Figure 2a).

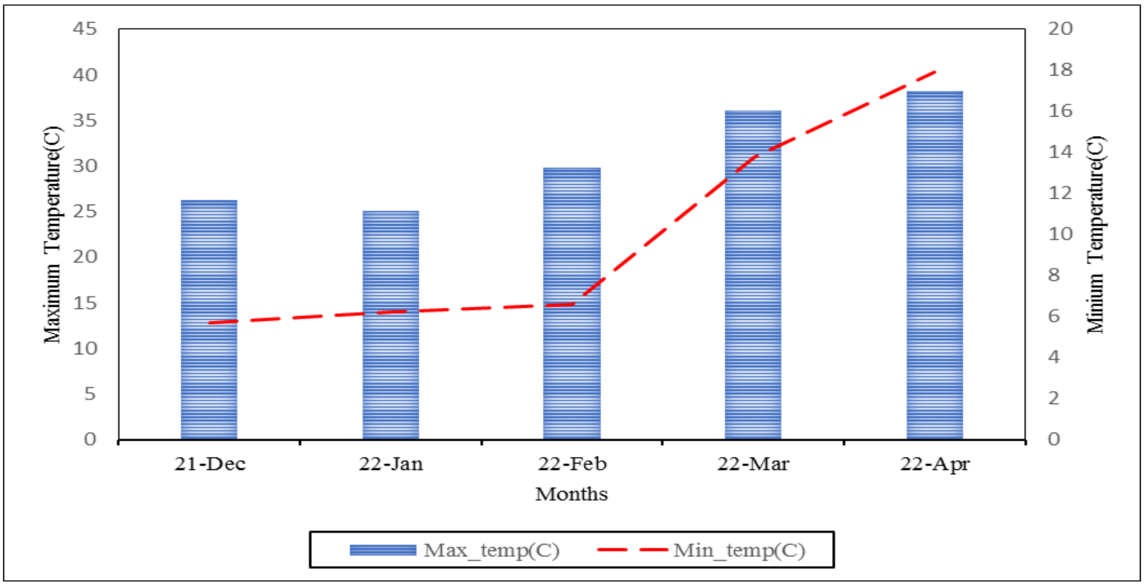


Figure 2(a): Maximum and minimum temperatures during experimental period

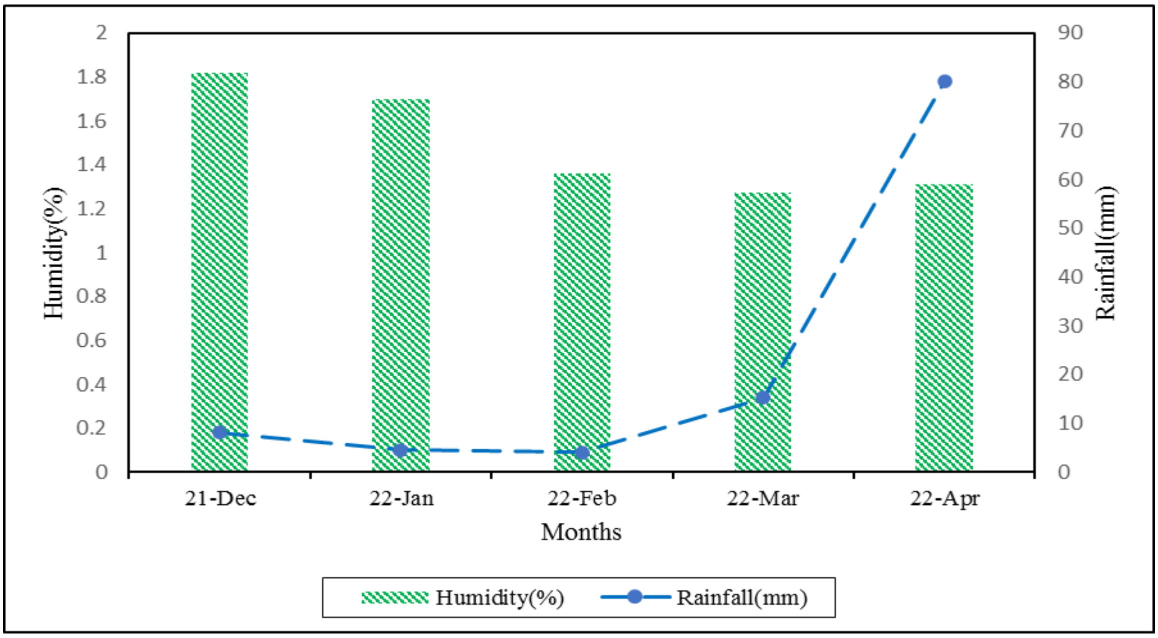


Figure 2(b): relative humidity and rainfall during experimental period

Besides, the highest humidity was shown in the month of December 2021 with 1.8% lowest at 1.3% recorded in the month of March 2022. There was no rainfall at the beginning but little bit rain before harvesting the experiment. The highest rainfall month was in April with the data being 80 mm. While very low percentage was shown from December 2021 to February 2022 and the range was between 5-10 mm shown in (Figure 2b).

3.3 Soil type

The soil of the experimental field belongs to the old Himalayan Piedmont Plain (AEZ-1). Soil with good drainage capacity. The experiment plot was medium high land with the pH range of6.12 *i.e.*, the soil is acidic soil. The soil physical and chemical properties of the experimental site were analyzed before started the experiment and presented in (Table 1). Soil analysis was done from the Soil Resource Development Institute (SRDI), Dinajpur, Bangladesh shown in (Table 1). Soil analysis showed that the soil of the experimental plot was sandy loam.

Table 1: Soil physical and chemical Properties of the experimental location

Parameters measured	Units	Soil Layer between (0-40) cm
Soil textural classes	-	Sandy loam
Sand	%	47.60
Silt	%	36.00
clay	%	16.40
Organic matter	%	0.31
Organic carbon	%	0.18
Total N	%	0.007
Total P	%	14.30
Available K	$mgkg^{-1}$	0.05
Available S	$mgkg^{-1}$	18.09
Field capacity	%	10.50
CEC	Meq 100g	1.00
Ec	$mgkg^{-1}$	87.30
pH	$mgkg^{-1}$	6.12

3.4 Duration of the experiment

The experiment was conducted during the period from 10 December 2021 to 8 April 2022.

3.5 Varieties/ planting material

BARI Shurjamukhi-2 was used in this experiment. Seeds were collected from Bangladesh Agricultural Research Institute, (BARI) Gazipur, Bangladesh.

3.6. Varietal characteristics of BARI Shurjamukhi-2

i. Developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh.
ii. Plants are tall, well growth, Plant height 125-140 cm.
iii. Large head, erect, uniform germination and seeds are attractive and eye catching.
iv. Radium 2.0-2.4 cm, ripen inflorescence of head radium 15-18 cm.
v. Seed colour black.
vi. Number of seed head^{-1} 350 – 450.

vii. Crop duration in rabi season (95-100) days and kharif season 85-90 days.

viii. Cultivation in rabi and kharif season.

ix. Yield in Rabi season (2.0-2.3) t ha^{-1} and kharif season 1.5-1.8 t ha^{-1}.

x. Oil content 42-44%.

xi. Overall, vigorous growth in this variety

3.7. Treatments

The experiment consists of the following seven treatments.

Factor A: Variety; **BARI Shurjamukhi-2**

Factor B: Seven treatments of different organic fertilizers

- T_1 = Control (no application)
- T_2 = Farm Yard Manure (FYM) @ 2 t ha^{-1}
- T_3 = Vermicompost (VC) @ 2 t ha^{-1}
- T_4 = Biochar (BC) @ 2 t ha^{-1}
- T_5 = Farm Yard Manure (FYM) @ 1 t ha^{-1} + Vermicompost (VC) @ 1 t ha^{-1}
- T_6= Farm Yard Manure (FYM) @ 1 t ha^{-1} + Biochar (BC) @ 1 t ha^{-1}
- T_7= Vermicompost (VC) @ 1 t ha^{-1} + Biochar (BC) @ 1 t ha^{-1}

3.8. Experimental layout and treatment combination

3.8.1. Experimental layout

The experiment was laid out in a Randomized Complete Block Design (RCBD).

3.8.2. Treatment combination

The experiment consists of seven treatment combinations where each treatment was replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the total number of the plot was 3 × 7 = 21. The unit plot size was (4 m × 2.5 m) *i.e*., 10 m^2. Irrigation and drainage channel was made by maintaining 50 cm width and 30 cm between the blocks and 25 cm wide and 25 cm depth between plots. The experimental layout and treatment combinations are shown in (Figure 3).

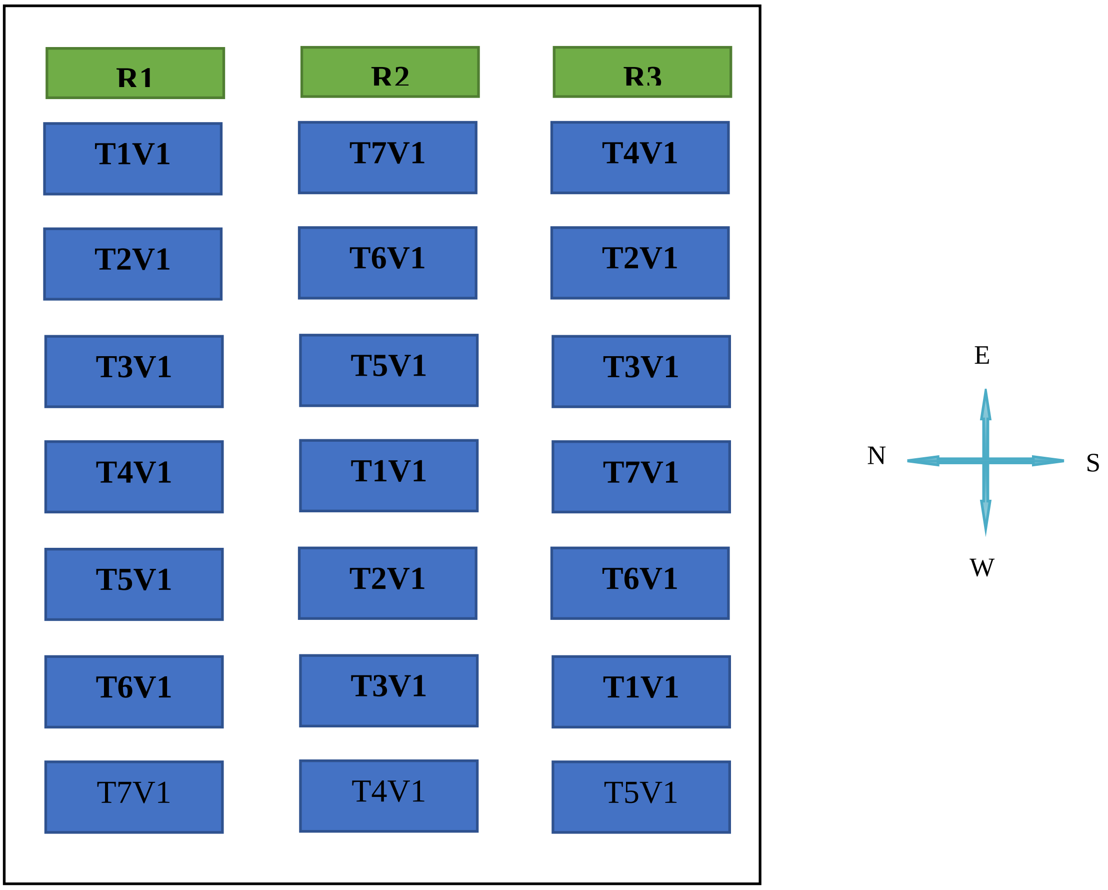


Figure 3: Layout of experimental plot

3.9. Experimental procedure and crop management

3.9.1. Collection of seed

The varieties were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Before sowing, the seeds were treated with vitavax-200 for germination in the laboratory and the percentage of germination was found to be over 90 % for the variety.

3.9.2. Land preparation

The experimental field was first ploughed on 10 December 2021. The clods of the land were hammered to make soil into small pieces. Weeds, stubbles, and crop residues were removed from the land. The final ploughing and land preparation was done on 12 December 2021. The layout was done as per experimental design on 13 December 2021.

3.9.3. Application of fertilizer

Fertilizer was applied as a source of N-P-K nutrients viz., 80 kg N_2, 40 kg P_2O_5, and 40 K_2O kg ha^{-1} uniformly distributed through Urea, DAP, and M_OP. Therefore, the fertilizer requirement was urea=80g/10 m^2 plot; DAP = 40 g/10 m^2 plot, and MoP = 40 g/10 m^2 plot respectively. Organic fertilizers were applied as per the treatments.

3.9.4. Treatment application

Different fertilizer application was done by following the treatments. Therefore, the treatments doses were applied as;

Treatments	Application Rate (Kg)
T_1 = Control (no application)	No fertilizer
T_2 = Farm Yard Manure (FYM) @ 2 t ha^{-1}	2 kg $plot^{-1}$ ($10m^2$)
T_3 = Vermicompost (VC) @ 2 t ha^{-1}	2 kg $plot^{-1}$ ($10m^2$)
T_4 = Biochar (BC) @ 2 t ha^{-1}	2 kg $plot^{-1}$ ($10m^2$)
T_5 = Farm Yard Manure (FYM) @ 1 t ha^{-1}+ Vermicompost (VC) @ 1 t ha^{-1}	(1 kg+1 kg) $plot^{-1}$ ($10m^2$)
T_6= Farm Yard Manure (FYM) @ 1 t ha^{-1}+ Biochar (BC) @ 1 t ha^{-1}	(1 kg+1 kg) $plot^{-1}$ ($10m^2$)
T_7= Vermicompost (VC) @ 1 t ha^{-1}+ Biochar (BC) @ 1 t ha^{-1}	(1 kg+1 kg) $plot^{-1}$ ($10m^2$)

3.9.5. Seed rate with spacing

The recommended seed rate (7 kg ha^{-1}) *i.e.*, 0.007 kg or 7 g/ 10 m^2 of Bari Surjamukhi-2 variety seed was used for a single plot. Therefore, a total of 147 g or .147 kg seed was required for a 210 m^2 or 21 plot area. Line to line distance was 30 cm. After placing the seeds on line, the seeds were covered with loose friable soil.

3.9.6. Seed sowing

After preparing the line spacing, seeds were sown in line on 27 December 2021 as per the experimental layout.

3.9.7. Intercultural operations

It is done to ensure that crops grow properly. Thinning and gap filling were done simultaneously at 15 and 30 days after sowing. The crops have emerged within 8 to 12 days. Irrigation was given seven times after a 5 to 10 days break in order to maintain a suitable moisture level. Another, operation weeding is done two times during the period.

3.9.8. Insect and pest control

There was no infection of disease in the field but the crop was infested with aphids at the time of flowering and was controlled successfully by spraying Ektara @ 0.02 g L^{-1} water.

3.9.9. Harvesting and threshing

The sunflower crop was harvested on April 8, 2022. Prior to harvest, plant samples from each unit plot were collected. To collect yield data, the samples were properly dried. After drying in the sun, each plot per seed and per plant seed was recorded. The seeds fresh and sundry weights were recorded.

3. 10. Data collection

Data were collected based on the yield and yield characteristics of the wheat plant. The characteristics were;

i. Plant height (cm)
ii. Stem diameter (cm)
iii. Leaves number plant $^{-1}$ (no.)
iv. Fresh weight of leaves (g)
v. Dry weight of leaves (g)
vi. Chlorophyll content (%)
vii. Leaf area index (%)
viii. Head diameter (cm)
ix. Weight of seed head^{-1} (g)
x. Seed number per head (no.)
xi. Thousand seed weight (g)
xii. Head yield (t ha^{-1})
xiii. Biological yield (t ha^{-1})
xiv. Stover yield (t ha^{-1})
xv. Seed yield (t ha^{-1})

xvi. Water holding capacity (%)
xvii. Harvest Index (%)

These data were taken when the crop attained maturity. Due attention was paid to recording the data as influenced by different organic fertilizer application was a prime objective of the present study. With this point of view, ten plants were randomly collected from each plot. From these, plant height, numbers of leaves plant^{-1}, stem diameter (mm), chlorophyll content (%), head diameter (cm) and thousand seed weight were noted. Data on seed yield, biological yield, and stover yield and harvest index were noted down on each plot.

3.10.1. Plant height (cm)

In every plot, ten plants are randomly selected for a measurement of the plant height. The plant height of the selected plant was measured from the ground level to the tip of the plant at 25, 50, 70, 90 DAS and harvesting stage. Plant height always measured in centimeter.

3.10.2. Stem diameter (cm)

Stem diameter measurement as the average thickness of the stem using measuring tape of selected ten plants and the mean obtained at 25, 50, 70, 90 DAS, and harvesting stage.

3.10.3. Leaves number plant^{-1} (no.)

It was also obtained by counting all the green leaves of ten plants at 25, 50, 70, 90 DAS, and at the harvesting stage.

3.10.4. Fresh weight of leaves (g)

Fresh weight of leaves was recorded in gram at 25, 50, 70, and 90 DAS.

3.10.5. Dry weight of leaves (g)

Dry weight of leaves was recorded in gram at 25, 50, 70, and 90 DAS.

3.10.6. Chlorophyll content (%)

The Chlorophyll content of the plant leaves was measured by using a CL-01 chlorophyll meter, and data was recorded at 60 DAS.

3.10.7. Leaf area index (%)

The leaf area index is a reliable parameter for studying the effects of the environment on plants. Leaves are one of the main plant organs and are responsible for the productivity of a plant. Selected ten plants from each plot were used to measure the leaf area. Leaf area (A) can be simply calculated by multiplying the product of leaf length (L) and leaf width (W) by a constant. It was recorded in cm. Finally, the leaf area index (LAI) was calculated using the following ratio;

Leaf area Index (LAI) = Total leaf area (cm^2)/ Total ground area (cm^2) from where the plants were sampled.

3.10.8. Head diameter (cm)

The flower head diameter was measured by using the ten selected plants per plot. Head diameter was measured in cm at 70 and 90 DAS.

3.10.9. Weight of seed head^{-1} (g)

The weight of seed per head was calculated in grams using the ten selected plants.

3.10.10. Seed number per head (no.)

Number of dried seeds was counted in individual flower head from selected ten plants after harvesting.

3.10.11. Thousand seed weight (g)

A total of 1000 dried seeds were collected from the ten plants that were chosen. After counting, the seeds were weight and converted the measurement into gram.

3.10.12. Seed yield t ha^{-1}

After harvest of the crop, seed from each unit plot was dried and weighed. The result was expressed as t ha' on 14% moisture basis. Seed yield was measured by the following formula;

Seed Yield=Biological Yield/Stover Yield

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

Biological yield is the total biomass produced above the soil. Biological yield was measured by the following formula and expressed in t ha^{-1};

Biological Yield=Seed Yield + Stover Yield

3.10.14 Stover yield (t ha^{-1})

After harvesting, the straw from each unit plot was dried in the sun and weighed. The result was expressed as t ha^{-1}. Stover yield was measured by the following formula;

Stover Yield=Biological Yield/Seed Yield

3.10.15. Water holding capacity (%)

Before started the experiment collected soil samples and after completed of the experiment, collected soil samples from the plot were sent to SRDI (Soil Resources Development Institute, Dinajpur) for analysis of the water holding capacity of the soil. It is always expressed in percentage (%).

3.10.16. Harvest index (%)

Harvest index was determined by dividing the economic yield (seed yield) to the biological yield (Seed yield + Stover yield) from the same area and then multiplied by 100. It is expressed by the following formula;

$$Harvest\ Index\ (\%) = \frac{Economic\ yield\,(Seed\ Yield)}{Biologicla\ Yield} \times 100$$

3.11. Data analysis using Statistical program

The analysis of variance (ANOVA) function, the relationship between different organic fertilizers, and variety, with yield attributes of sunflower evaluated by the least significant difference (LSD) used for mean comparisons at a 5% probability level using Statistics 10.1. Mean comparison between the treatments, and combination of the treatments were done by using the R program (version 4.2.1). Comparison graphs were done by Microsoft Excel programming. Origin Pro 2022 (version-9.8.200) software used to do the weather graphs.

CHAPTER IV

RESULT AND DISCUSSION

The chapter comprises of the presentation and discussions of the results obtained due to different of treatments application in sunflower production. Analyzed data on different parameters are recorded and presented. These results have been presented and discussed with the help of table and graphs.

4. 1. Combined analysis of variance (ANOVA)

Combined analysis of variance results showed for nineteen yield related traits for the variety BARI Shurjamukhi-2. From (Table 2) ANOVA result showed highly significant differences between replication to replication for plant height (13.20), seed diameter (12.04), and leaf area index (2.17).

Table 2: Analysis of variance on yield, yield characteristics of sunflower as affected by organic fertilizers

Source of variation	df	PH (cm)	SD (cm)	LN_P (no)	L.L (cm)	LAI	FW_LP (g)
Replications (Factor A)	2	13.20**	12.04*	14.50^{ns}	15.20^{ns}	2.17*	11.21^{ns}
Treatments (Factor B)	6	5.44**	4.35**	7.80**	17.22*	0.51*	7.55**
Replications × Treatments	12	6.13**	7.08**	11.23**	6.30*	0.47*	7.87**
Residual	20	0.89	0.78	0.56	0.77	1.07	2.30
CV (%)		13.51	14.22	11.20	1.20	23.76	17.20
LSD		1.10	2.04	1.08	0.05	1.07	0.89

Here, PH=Plant Height; SD= Stem Diameter; LN_P=Leaf number per plant; LAI= Leaf Area Index; FW_LP = Fresh Weight of Leaves Plant^{-1} and ns: non-significant, *: significant at 0.05 and **: significant at 0.01 probability level

Non significant variation shown for leaves number plant^{-1} (14.50) and fresh weight of leaves plant^{-1} (11.21). Treatment to treatment showed highly significant differences for leaf length (17.22), and (7.80) for leaf number plant^{-1}. While treatment combination showed significant variation for leaf number plant^{-1} (11.23), fresh weight of leaves plant^{-1} (7.87) shown in (Table 2).

Table 3 showed that treatment to treatment significant differences for fresh weight of plant^{-1} (88.43), dry weight of leaves plant^{-1} (52.37), dry weight of plant^{-1} (39.23), chlorophyll content (28.20), and 1000-seeds weight (12.78). Only flower head diameter (0.78) showed non significant.

Table 3: Analysis of variance on yield, yield characteristics of sunflower as affected by organic fertilizer treatments

Source of variation	df	DW_LP (g)	FW_P (no.)	DW_P (no.)	CC (%)	FH_D	1000-SW
Replications (Factor A)	2	52.37**	88.43*	39.23*	28.20*	0.78^{ns}	12.78*
Treatments (Factor B)	6	47.05*	66.55**	48.45**	104.23*	24.67**	1180.64**
Replications ×Treatments	12	105.65**	5.78**	4.88**	4.31*	5.67**	4.01**
Residual	20	1.39	0.88	1.02	1.02	1.56	294.48
CV%		14.46	12.20	14.20	11.34	10.56	2.93
LSD		1.05	1.04	0.89	1.26	1.78	1.20

Here, DW_LP=Dry Weight of leaves plan^{-1}; FW_P=Fresh weight plant^{-1}; DW_P= Dry weight plant^{-1}; CC=Chlorophyll Content, FH_D =Flower Head diameter^{-1}; 1000-SW= 1000 Seed weight. Here: ns: non-significant, *: significant at 0.05 and **: significant at 0.01 probability level

Treatment to treatment showed significant differences for 1000-seeds weight (1180.64), chlorophyll content (104.23), fresh weight plant^{-1} (66.55), dry weight plant^{-1} (48.45), dry weight of leaves plant^{-1} (47.05), and flower head diameter (24.67). Moreover, their combination showed highly significant differences for dry weight of leaves plant $^{-1}$ (105.65).

Table 4: Analysis of variance on yield, yield contributing characters of sunflower as affected by organic fertilizer treatments

	df	F.D.W_F.H (g)	F.D.S.N_H (no.)	SW_H (t ha^{-1})	HI (%)	SY (t ha^{-1})	BY (t ha^{-1})	SY (t ha^{-1})
Replication (Factor A)	2	30.10**	45.22*	56.10*	34.12^{ns}	0.001^{ns}	0.069*	1.01*
Treatments (Factor B)	6	337.71**	128.32*	109.21*	102.11*	0.442**	1.62**	2.05**
Replication × Treatment	12	9.07**	4.67*	5.77*	1.21^{ns}	0.002^{ns}	0.02**	0.004**
Residual	20	37.22	23.33	21.20	35.12	282.18	91.32	479.16
CV%		7.77	4.21	3.88	5.66	6.56	8.45	2.47
LSD		1.21	0.89	0.92	1.01	1.11	1.26	1.10

Here, F.D.W_F.H = Fresh and Dry weight of flower head; F.D.W.N_H=Fresh and Dry seed number head^{-1}; SW_H= Seed weight head; SY=Stover yield and ns: non-significant*: significant at 0.05 and **: significant at 0.01 probability level

Table 4 showed replication to replication significant differences for seed weight head^{-1} (56.10), fresh and dry seed number head^{-1} (45.22), and fresh and dry weight of flower head (30.11). While non significant differences shown for harvest index (34.12) and seed yield (0.001). Treatment to treatment showed significant differences for fresh and dry weight of flower head (337.71), fresh and dry seed number head^{-1} (128.32), seed weight head^{-1} (109.21), harvest index (102.11) and seed yield (2.05). And their combination showed highly significant differences for fresh and dry weight of flower head (9.07), seed weight head^{-1} (5.77), and fresh and dry seed number head^{-1} (4.67). However, non significant relation showed for harvest index (1.21) and seed yield (0.002). Khodaei-joghan *et al*. (2018) described that the observed highly significant large variation between the yield contributing characters with the replication and treatments specified that selection of agronomic traits could be helped to measure the variation between the treatments with variety. While only stover yield had only a non significant variation with the interaction between replication and treatments.

4.2. Plant height (cm)

Plant height was found to be statistically significant at 25, 50, 70, 90 DAS, and at harvesting stage with different organic fertilizers and their combinations (Figure 4). During harvesting time, the longest plant height was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (181.0 cm) and the shortest plant height was obtained from T_1 (control) with (99.7 cm). After that, the second highest plant height was observed at 90 DAS with the longest plant height was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (176.7 cm) and the shortest plant height obtained from T_1 (control) *i.e.*, (98.7 cm). ha^{-1} control treatment. At 70 DAS, the longest plant was recorded from T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) (153.0 cm) and the shortest plant height obtained from T_1 (control) (93.33 cm). At 50 DAS, the longest plant was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) (106.33 cm) and the shortest plant height obtained from T_1 (control) (86 cm). While at 25 DAS, the longest plant was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) (30.17 cm) and the shortest plant height obtained from T_1 (Control) with (14.7 cm). Results showed that due to the combination of T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) increased the plant height compared to the other treatment combinations.

Application of vermicompost with biochar also significantly improved agronomic traits like plant height reported by (Janmohammadi *et al*., 2016). Application of FYM at the rate of 10 and 20 t ha^{-1} recorded significant improvement in the plant height production of sunflower after 25 days of sowing over no FYM. FYM @10 and 20 t ha^{-1} increased the plant height by 11 and 5.4 %, respectively over no application reported by (Rasool *et al*., 2013). Hjartardóttir (2017) showed the similar result by using (200 g pot^{-1} +400 g pot^{-1}) of farm yard manure and biochar increased the plant height. Naglaa *et al*. (2022) reported that the data showed that the highest value of plant height (341.8 ± 11.01 cm), after the application of inorganic fertilizer, while the use of compost coupled (CCB) with biochar (BC) contributed to a substantial increase in the production yield of sunflower seeds, oil, and a high stalk yield compared with inorganic treatment. Biochar and vermicompost application had a positive effect on sunflower growth characters together and will be beneficial in obtaining the highest healthy, high-quality seed and oil yield reported by (Takaragawa *et al*., 2020 and Volkan Gül *et al*., 2021).

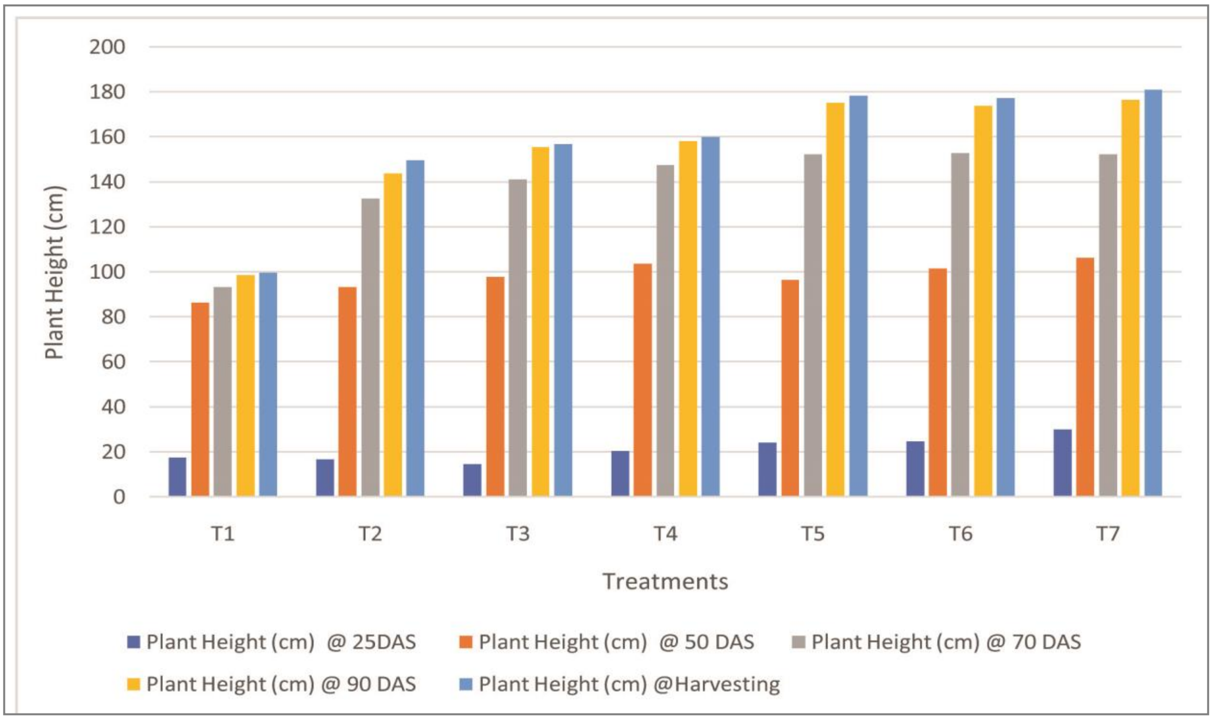


Figure 4: Effect of different organic fertilizers treatment on plant height of sunflower at different days after sowing (at 25, 50, 70, 90 DAS and harvest) respectively.

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 t ha^{-1}+ VC @ 1 t ha-^{1}

T_6= FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.2. Stem diameter (cm)

Stem diameter was found to be statistically significant at 25, 50, 70, 90 DAS, and at harvesting time (Figure 5). During harvesting time the highest stem diameter was recorded from T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (11.7 cm) and the minimum stem diameter was obtained from T_1 (control) (3.7 cm). While at 25 DAS, the maximum stem diameter was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) (4.1 cm) and the minimum stem diameter was obtained from T_1 (control) (0.4 cm). At 50 DAS, the maximum stem diameter was recorded from T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) (6.8 cm) and the minimum stem diameter obtained from T_1 (0.72 cm) *i.e.*, with control. At 70 DAS, the second maximum stem diameter was recorded from T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-}

^{1}+ BC @ 1 t ha^{-1}) with (9.3 cm) and the minimum stem diameter obtained from T_1 (2.5 cm). At 90 DAS, the maximum stem diameter was recorded from T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) recorded the same result so not significant (11.7 cm) and the minimum stem diameter obtained from T_1 (control) with (3.6 cm). Whether for stem diameter, the combination of FYM and VC *i.e.*T_5 and FYM with BC *i.e.*T_6 showed the highest result.

Naglaa *et al.* (2022) reported that the highest value of stem diameter was measured after the application of compost coupled (CCB) with biochar (BC) to a substantial increase of stem diameter compared with inorganic *i.e.*, chemical treatment. Byra reddy *et al.* (2018) concluded that FYM application at 4 t ha^{-1} recorded taller plants with higher value of stem diameter per plant as against no FYM addition. Mokgolo *et al*. (2019) reported that the application of organic manure had a significant effect on sunflower grain yield, dry matter, head dry matter, plant height, and stem diameter throughout all growing stages of the selected cropping season with vermicompost with biochar manure producing the best values.

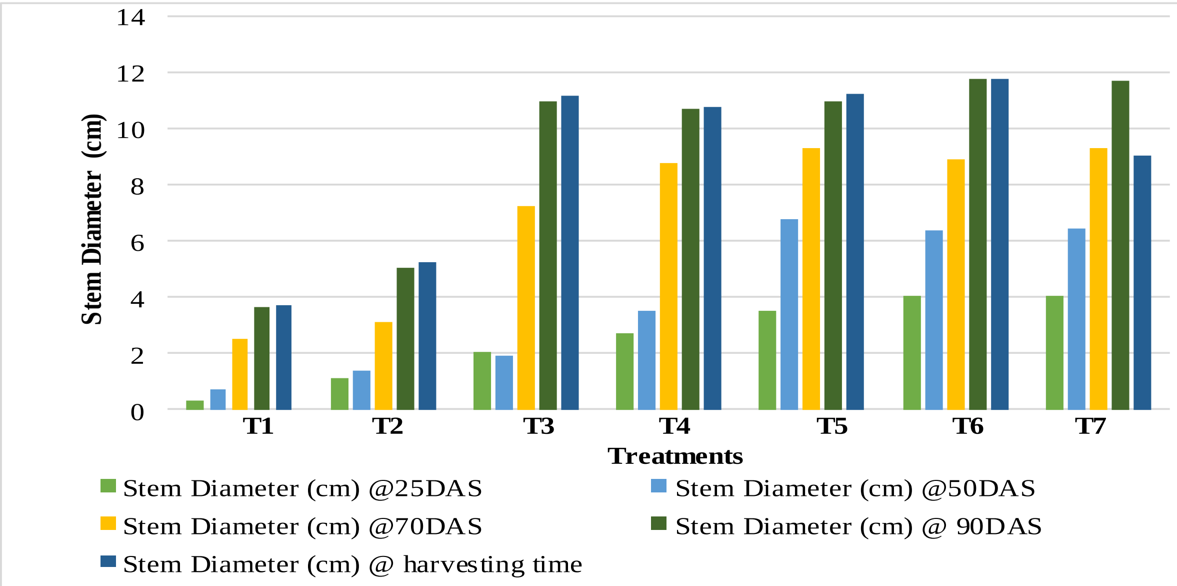


Figure 5: Effect of different organic fertilizer treatments on stem diameter of sunflower at different days after sowing (at 25, 50, 70, 90 DAS and harvesting stage)

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha-^{1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.3. Leaves number plant^{-1}

Leaves number plant^{-1} was found to be significant statistically at 25, 50, 70, 90 DAS, and at harvesting time (Figure 6). The figure showed that at harvesting time the maximum number of leaves was recorded fromT_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (48.7 number), and the lowest number of leaves obtained from T_1 (control) with (26.3 no.). At 90 DAS the second highest number of leaves was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (45 number), and the lowest number of leaves obtained from T_1 (26.2) at control treatment. Besides, at 25 DAS *i.e.*, at the earlier or vegetative stage the highest number of leaves per plant was recorded from T_5 (FYM @ 1t ha^{-1} + VC @ 1 t ha^{-1}), T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1} + BC @ 1 tha^{-1}) with (19.7 no.) and the lowest number of leaves obtained from T_1 (8.7) *i.e.*, at control treatment. While at 50 DAS the highest number of leaves was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (39.7 no.) and the lowest number of leaves was obtained from T_1 (23.3) at control. At 70 DAS, the highest number of leaves was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (43.7), and the lowest number of leaves obtained from T_1 (26) at control treatment.

The improvement in nutritional status of the sunflower plant might have resulted in the greater synthesis of amino acids and protein and other growth promoting substances, which seem to have enhanced the meristematic activity; increased cell division with enlargement and the results of the present investigation were in close conformity with the findings of Solangi *et al*. (2015). Byra reddy *et al*. (2018) concluded that FYM application at 4 t ha^{-1} recorded the highest number of leaves per plant as against no FYM addition.

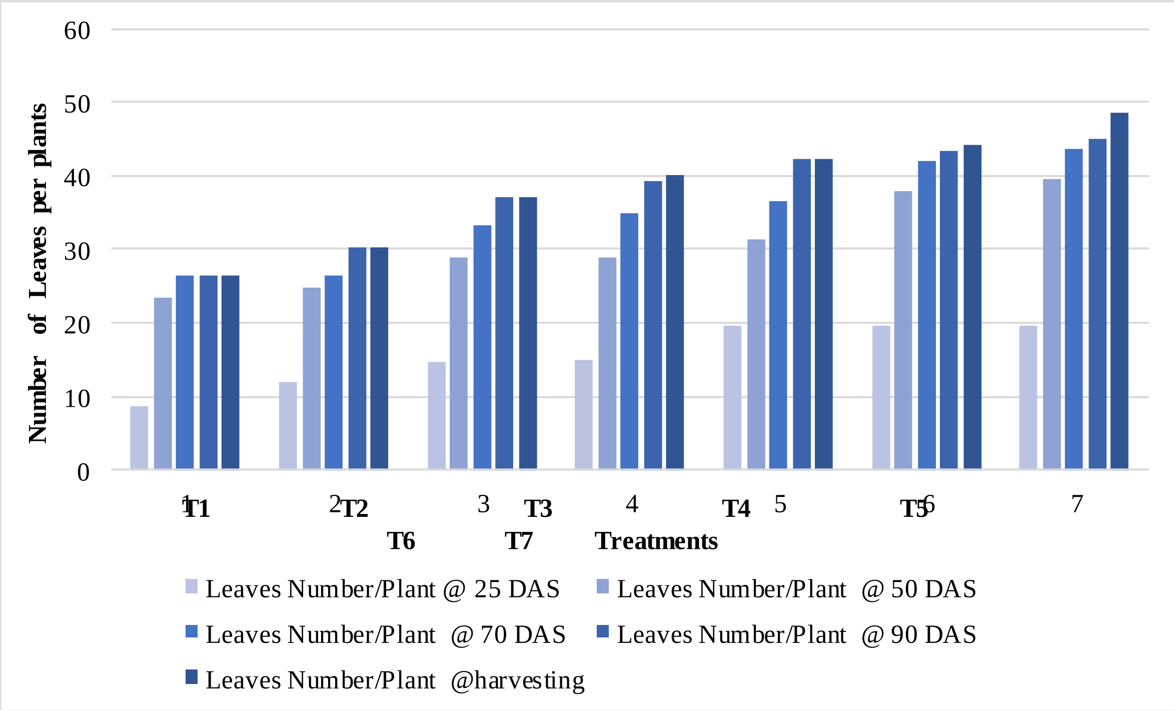


Figure 6: Effect of different organic fertilizers treatments on leaves number per plant of sunflower at different days after sowing at 25, 50, 70, 90 DAS and harvesting stage

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.4. Fresh weight of leaves plant^{-1} (g)

Different fertilizer managements showed a significant variation on above ground fresh weight plant^{-1} for all growth stages. The result revealed that the fresh weight of leaves plant^{-1} differentiated statistically at 25, 50, 70, and 90 DAS (Figure 7). At 90 DAS, the maximum fresh weight of leaves plant^{-1} was recorded from T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) with (12.5 gm), and the minimum fresh weight of leaves obtained from T_1 (4.9 g) at control treatment. At 70 DAS, the maximum fresh weight of leaves plant^{-1} was recorded from T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (12.4gm) and the lowest fresh weight of leaves plant^{-1} obtained from T_1 (control) (4.1 gm). While at 50 DAS, the maximum fresh weight of leaves was recorded from T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (9.5 gm) and the minimum fresh weight of leaves obtained from T_1 (1.5 g) *i.e.*, at control treatment. at 25 DAS, the maximum fresh weight of leaves was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (3.0 g) and the minimum fresh weight of leaves obtained from T_1 (1.1 g) *i.e.*, at control treatment. Similar findings was also observed by Iqbal *et al*. (2020) in application of Moringa leaf extract (MLE) @ 50% produced maximum fresh weight of leaves $plant^{-1}$ of sunflower. Similar result was reported by Ahmad *et al.* (2008). and Nyangani *et al*. (2010) reported that the incorporation of organic manures and rate of mineral fertilizers significantly influenced the fresh weight of leaves per plant. Chopra *et al*., (2016) reported that combined effect of variety and organic fertilizer

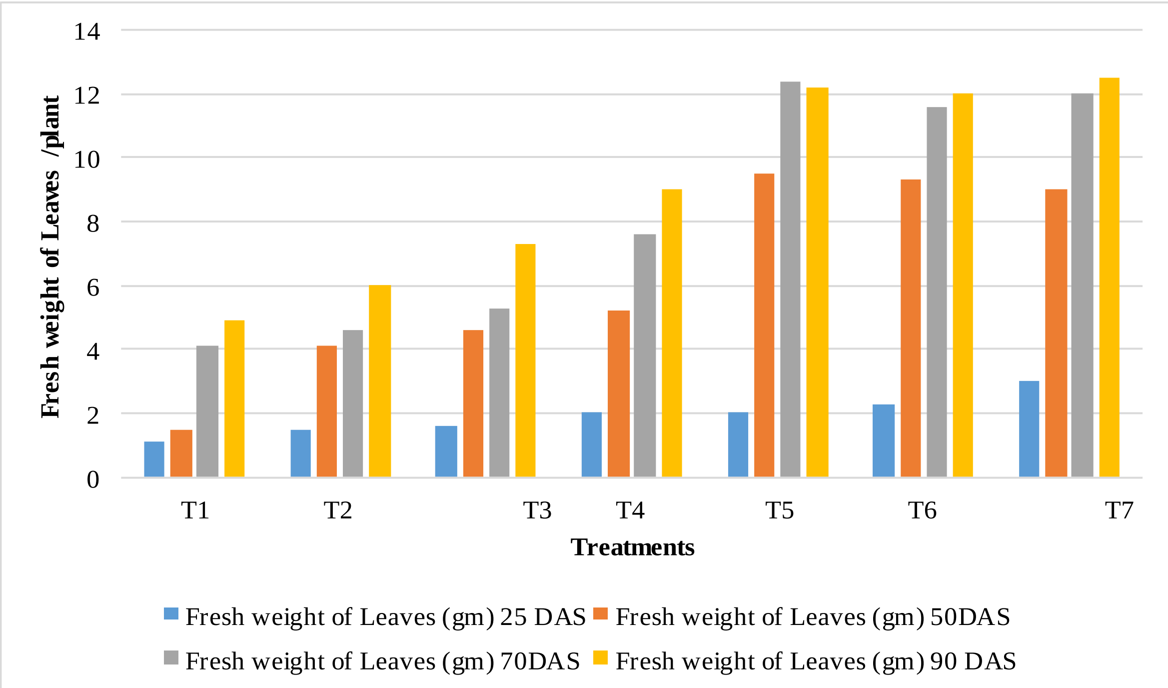


Figure 7: Effect of different organic fertilizers treatments on fresh weight of leaves per plant of sunflower at different days after sowing at 25, 50, 70, 90 DAS and harvesting stage

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seem to have enhanced the meristematic activity and increased cell division and enlargement and elongation resulting in higher plant height and number of leaves consequently dry matter weight increased as well.

4.5. Dry weight of leaves plant^{-1} (g)

Different organic fertilizer managements showed a significant variation on above ground dry matter weight plant^{-1} for all growth stages. The different treatments showed a significant variation in dry weight of plant leaves demonstrated statistically at 25, 50, 70, and 90 DAS in (Figure 8). Result showed that at 25 DAS, maximum dry weight leaves were recorded from T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) (0.58 g) and minimum dry weight at T_1 (Control). At 50 and 70 DAS, the maximum dry weight leaves were recorded from T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (2.45 g); (2.92 g). At 90 DAS, the maximum dry weight of leaves was recorded from T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) with (3.15 g), and the minimum dry weight of leaves obtained from T_1 (2.26 g), At 70 DAS, the minimum dry weight leaves were recorded from T_2 (1.2 g), at 25 and 50 DAS, the minimum dry weight leaves were recorded from T_1 (Control).

Matome Mokgolo *et al*. (2019) reported that the application of organic manure had a significant effect on sunflower dry matter weight of leaves throughout all growing stages of the selected cropping season with vermicompost with biochar manure producing the best values. The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the meristematic activity and increased cell division and enlargement and their elongation resulting higher plant height and no of leaves consequently dry matter weight increased as well.

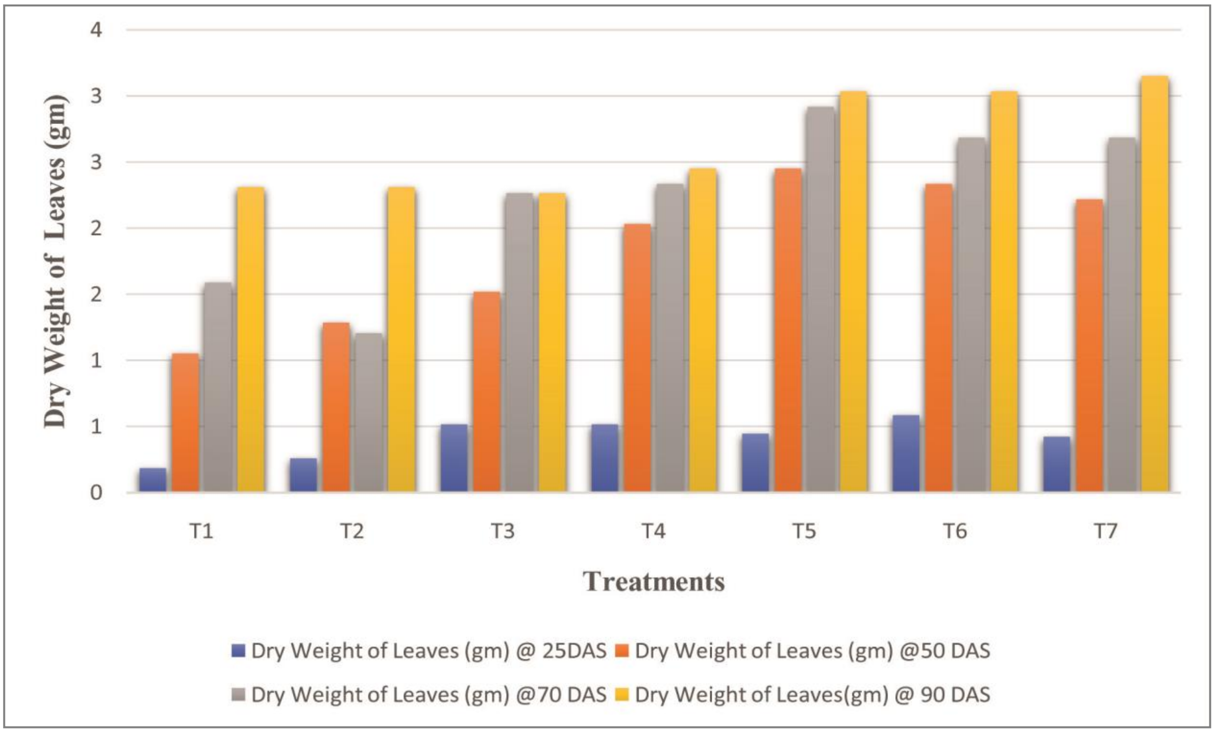


Figure 8: Effect of different organic fertilizers treatments on dry weight of leaves per plant of sunflower at different days after sowing at 25, 50, 70, 90 DAS and harvesting stage

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.6. Fresh weight of plants (g)

Different fertilizer managements showed a significant variation on above ground fresh weight plant for all growth stages. The results revealed that at 25 the highest fresh weight of plants (6.8 g) at T_5 (FYM @ 1t ha^{-1} + VC @ 1 t ha^{-1}), at 50 DAS, time the highest fresh weight of plants (26.7 g), at T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}). At 70, 90 DAS and at harvesting time the highest fresh weight of plants (40.30g, 84.33 g and 97.8 g respectively) were recorded from treatment T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}). While the lowest fresh wt. of plants at (3.64 g) were recorded from treatment T_1 (control) at 25 DAS (Figure 9). Then T_4 showed that second lowest fresh wt. of plants (4.0g) at 25 DAS. Second highest fresh weight of plants shown at T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}). at 70, 90 DAS, and at harvesting time was the lowest weight recorded (21.7 g, 39.9 g, 44.33 g respectively) T_1 (Control).

Similar result was reported (Ahmad *et al*., 2008). The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the meristematic activity and increased cell division and enlargement and their elongation resulting in higher plant height and no of leaves consequently dry matter weight increased as well.

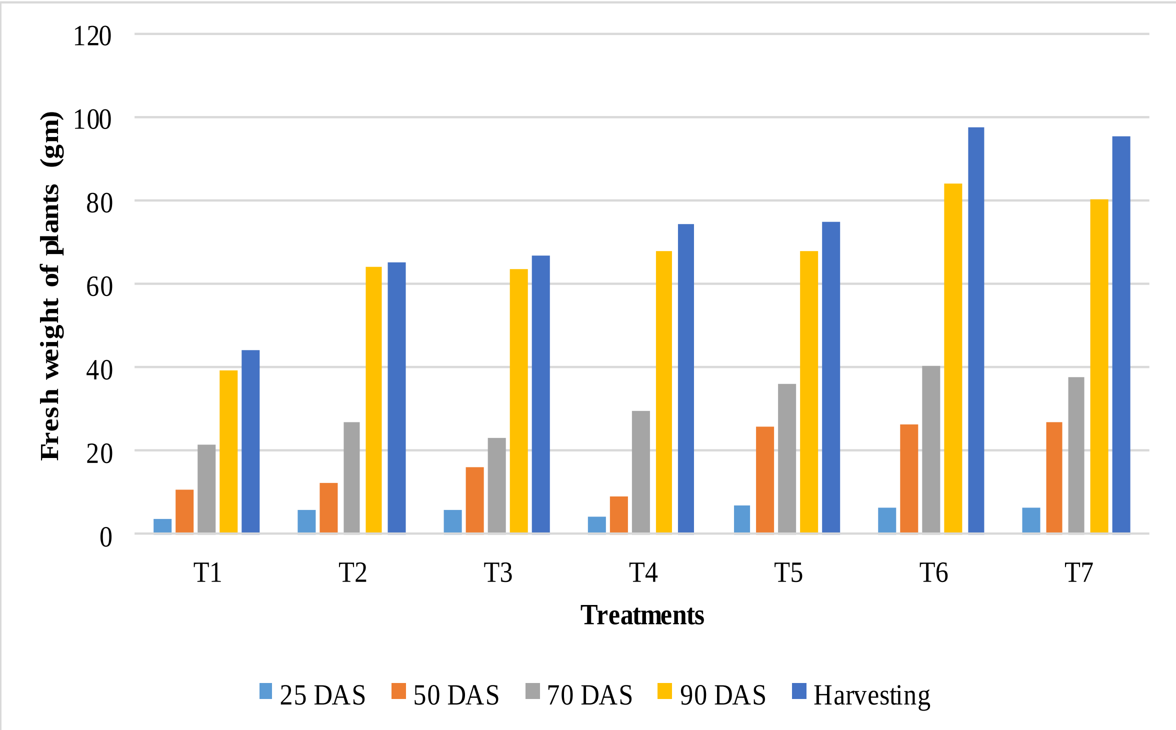


Figure 9: Effect of different organic fertilizer treatments on fresh weight of plant of sunflower at different days after sowing at 25, 50, 70, 90 DAS and harvesting stage

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.7. Dry weight of plants (g)

Different fertilizer managements showed a significant variation on above ground dry weight plant for all growth stages. The results revealed that at 25, 50, 70 and 90 DAS the highest dry weight of plants (1.6 g) at T_3 (VC @ 2 t ha^{-1}), (14.0 g, 15.0 g, 32.4 g, and 45.95 g respectively) observed at maximum dry weight of plants observed at T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) shown in (Figure 10). Then T_5 showed that lowest dry weight of plants (0.7 g) at 25 DAS. At 50 the lowest dry wt. of plants (3.4 g) at T_4 (BC @ 2 t ha^{-1}), At 70 DAS, 90 DAS, and at harvesting the lowest dry wt. of plants (4.3 g, and 4.55 g and 4.89 respectively) recorded in T_1 (control).

Similar result was reported (Ahmad *et al.*, 2008). Matome Mokgolo *et al*. (2019) reported that the application of organic manure had a significant effect on sunflower dry matter weight of plants throughout all growing stages of the selected cropping season with vermicompost with biochar manure producing the best values. The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the meristematic activity and increased cell division and enlargement and their elongation resulting in higher plant height and no of leaves consequently dry weight of plant increased as well.

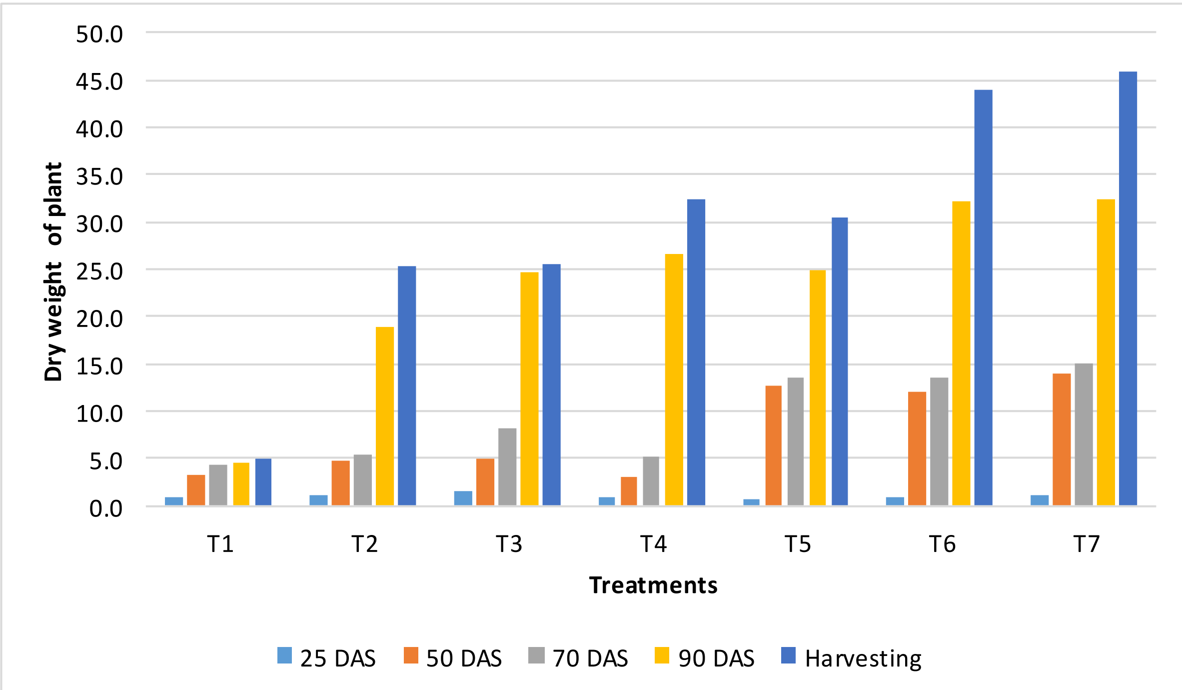


Figure 10: Effect of different organic fertilizer treatments on the dry weight of plant of sunflower at different days after sowing at 25, 50, 70, 90 DAS and harvesting stage.

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.8. Leaf Length (cm)

Different fertilizer managements had significant influenced on leaf length of sunflower at all the growth stages. The results revealed that at 25 DAS, the highest leaf length (22.55 cm) was recorded from treatment T_7 (BC @ 1 t ha^{-1}+ FYM @ 1 t ha^{-1}) while the lowest leaf length recorded from

Table 5: Effect of different organic fertilizer treatments on leaf length and leaf area index and of sunflower

Treatments	Leaf Length (cm)				Leaf area index			
	25 DAS	50 DAS	70 DAS	90 DAS	25DAS	50DAS	70 DAS	90 DAS
T_1	8.80^{e}	13.07^{e}	18.99^{f}	22.76^{d}	0.24^{e}	0.64^{c}	0.66^{c}	0.68^{e}
T_2	19.83^{c}	22.19^{d}	33.59^{e}	40.00^{c}	0.95b^{c}	0.96^{b}	0.98^{b}	1.07^{d}
T_3	18.70^{cd}	25.49^{c}	35.73^{d}	40.31^{c}	0.91b^{c}	0.96^{b}	0.98^{b}	1.08^{d}
T_4	19.92^{c}	35.17^{ab}	38.20^{c}	40.80^{c}	0.84^{cd}	0.95^{b}	0.97^{b}	1.10^{c}
T_5	21.86^{bc}	36.26^{a}	40.03^{b}	43.32^{b}	1.00^{bc}	1.20^{a}	1.36^{a}	1.40^{a}
T_6	21.50^{b}	33.31^{b}	40.19^{b}	46.33^{ab}	1.11^{ab}	1.23^{a}	1.35^{a}	1.40^{a}
T_7	22.55^{a}	36.25^{a}	42.43^{a}	47.61^{a}	1.16^{a}	1.20^{a}	1.33^{a}	1.35^{b}
LS	*	*	*	NS	*	NS	*	NS
CV %	22.45	22.71	16.08	16.93	11.95	14.13	12.06	21.95
LSD	9.549	22.11	15.32	16.26	0.1815	0.1896	0.1224	0.1642

In a column, figure bearing same, or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test. ** = Significant at 1% level of probability* = Significant at 5% level of probability. LS= Level of significance; CV= Co-efficient of variance, LSD= Least Significant Difference

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_1 (8.80 cm) in control, which is statistically dissimilar with other treatments. At 50 DAS the highest leaf length recorded from T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (36.26 cm), and from T_7 (BC @ 1 ha^{-1}+ FYM @ 1 t ha^{-1}) with (36.25 mm) while the lowest leaf length recorded from T_1 (13.07 cm) respectively. Then the results revealed that at 70 DAS the highest leaf length recorded from T_7 (BC @ 1 t ha^{-1}+ FYM @ 1 t ha^{-1}) with (42.43 mm), which was statistically dissimilar with T_2, T_4, T_5, and T_6 (18.99, 33.59, 35.73, 38.20, 40.03, and 40.19 mm, respectively), while the lowest leaf length was obtained from T_1 (18.99 mm). At 90 DAS, the highest leaf length was recorded from treatment T_7 (BC @ 1 t ha^{-1}+ FYM @ 1 t ha^{-1}) while the lowest leaf length was recorded from T_1 (22.76 mm) (Table 5). Singh *et al*. (2018) reported that the recommended doses of fertilizer (RDF), along with organic manure help to increase the leaf area index of different crops, also reported similar findings.

4.9. Leaf area index

Different organic fertilizer managements had significant influenced on the leaf area index of sunflower at all the growth stages (Table 5). The results revealed that at 25 DAS, the highest leaf area index (1.16.) was recorded from treatment T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}). While the lowest leaf area index was recorded from T_1 (0.24). At 50 DAS, the highest leaf length width ratio was recorded from T_6 (1.23) (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) while the lowest leaf area index was recorded from T_1 (control) (0.64), respectively which is statistically non significant with other treatments. Then, the results revealed that at 70 DAS, the highest leaf area index was recorded from T_5 (1.36) (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) and the lowest leaf width ratio was recorded from T_1 (Control). At 90 DAS, the highest leaf area index was recorded from T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) and T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) (1.40 and 1.40), respectively. However, the lowest leaf area index was recorded from T_1 (0.68) (Table 5). Singh *et al*. (2018) who reported that the recommended doses of fertilizer (RDF), along with organic manure help to increase the leaf area index of different crops also reported similar findings. Munir *et al*. (2007) also found that addition of inorganic nitrogen improved nutrients availability and uptake which led to increased achene and biological yields as a result of increased leaf area index, crop growth rate and net assimilation rate as well as biomass formation in Afghanistan.

4.10. Chlorophyll content (%)

Chlorophyll content was an important parameter in the production. It was varied from treatment to treatments. It was found to be significant statistically at 25, 50, 70, and 90 DAS shown in (Figure 11). At 25 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (90.60 %) and the lowest result was recorded T_1 (64.64 %) *i.e.*, at control treatment. At 50 DAS, the highest result was recorded from T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (109.03 %) and the lowest was T_1 (70.83 %). At 70 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (193.67 %) and the lowest was T_1 (81.67 %).

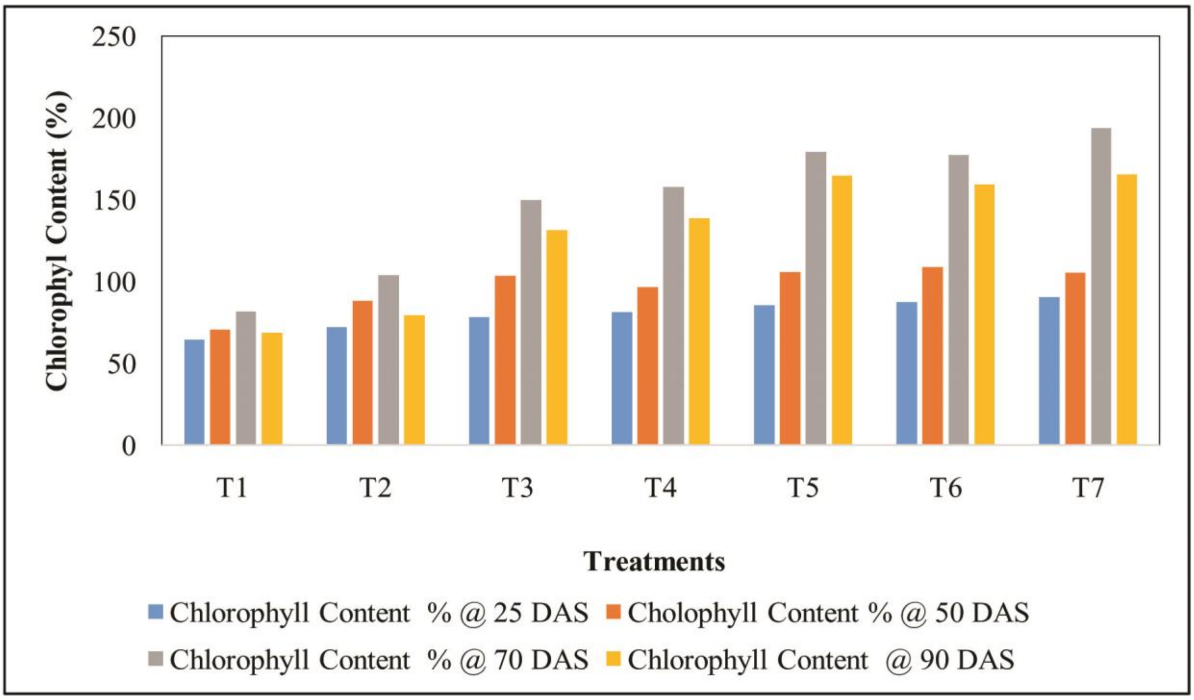


Figure 11: Effect of different organic fertilizer treatments on chlorophyll content (%) of leaves per plant at different days after sowing at 25, 50, 70, and 90 DAS of sunflower

Legend:

T_1 = Control (No application)
T_2= FYM @ 2 t ha^{-1}
T_3= VC @ 2 t ha^{-1}
T_4= BC @ 2 t ha^{-1}
T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}
T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}
T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

At 90 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (165.67 %), also T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}), showed the close at T_7 the lowest was T_1 (164.67%). Chlorophyll and total soluble protein contents were linked to chloroplast membrane organization, new leaves formation, individual leaf expansion, and process of mobilization of various pools of nitrogen from older leaves at different levels of nitrogen. (Kumari, 2017).

4.11. Flower head diameter (cm)

In the application of different organic fertilizer and treatments had a significant impact on the disc diameter in different growth stages. The result showed that at T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) treatment, the highest flower head diameter observed at harvesting stage with (30 cm) shown in (Figure 12). In contrast, the lowest result was recorded at 70 DAS with (23.3 cm). At T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 ha^{-1}) treatment, the highest flower head diameter was seen at harvesting stage (29 cm) and the lowest result was recorded (20 cm) at 70 DAS. Very lowest performance was shown by T_1 treatment *i.e.*, at control for all stages. Balalic *et al.* (2016) reported that fertilizer management had significant influence on head diameter in the stage of flowering and physiological maturity in sunflower. With later sowing head diameter increased, so the significantly highest head

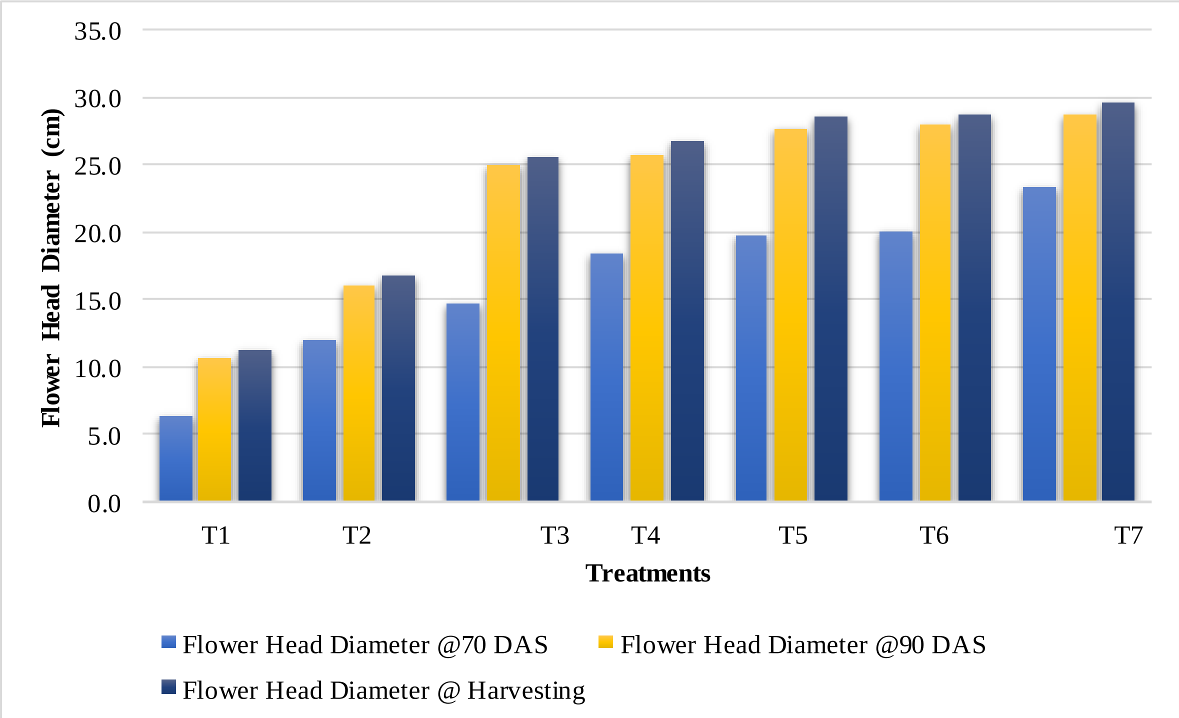


Figure 12: Effect of different organic fertilizer treatments on flower head diameter at different days after sowing at 70, 90 DAS and harvesting stage of sunflower

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

diameter across was found (11.8 cm) in the flowering stage, 22.6 cm at the stage of physiological maturity. Similar findings were observed by Solangi *et al*. (2015) that the head diameter is highest (19.49 cm), in the use of integrated nutritional levels *i.e.,* 6 t ha^{-1} poultry manure + 75% recommended dose of biochar fertilizers. Moreover, the lowest head diameter was observed under the treatments with control and a higher dose of fertilizer. After that, they suggested that combined use biochar with FYM resulted in greater seed number $head^{-1}$, head size, and the number of seeds per head of sunflower.

4.12. Fresh and dry weight of seed $head^{-1}$ (g)

Fresh and dry head weight was found to be statistically significant variation from treatments to treatments shown in (Figure 13). After harvesting, the highest fresh weight was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (342 g). After that, gradually decreased at T_6, T_5, T_4, T_3, T_2 and T_1 above this the weight respectively (338, 330, 320, 255, 200, and 82) g respectively. The dry weight of the flower head was highest T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (104 g) and then decreased significantly at T_5, T_4, T_6, T_3, T_2, T_1 with (97, 96, 95, 53, 46 and 15) g respectively.

Similar findings observed by Solangi *et al*. (2015) they conduct an experiment and the experiment shown the result that the seeds $head^{-1}$ is highest (650.91), in use of integrated nutritional levels *i.e.*, 6 t ha^{-1} poultry manure + biochar. Moreover, the lowest seeds $head^{-1}$ observed under the control treatment. Then they also suggested that combined use of biochar with FYM resulted in greater seed index, significant increase in plant height, head size and number of seeds per head of sunflower.

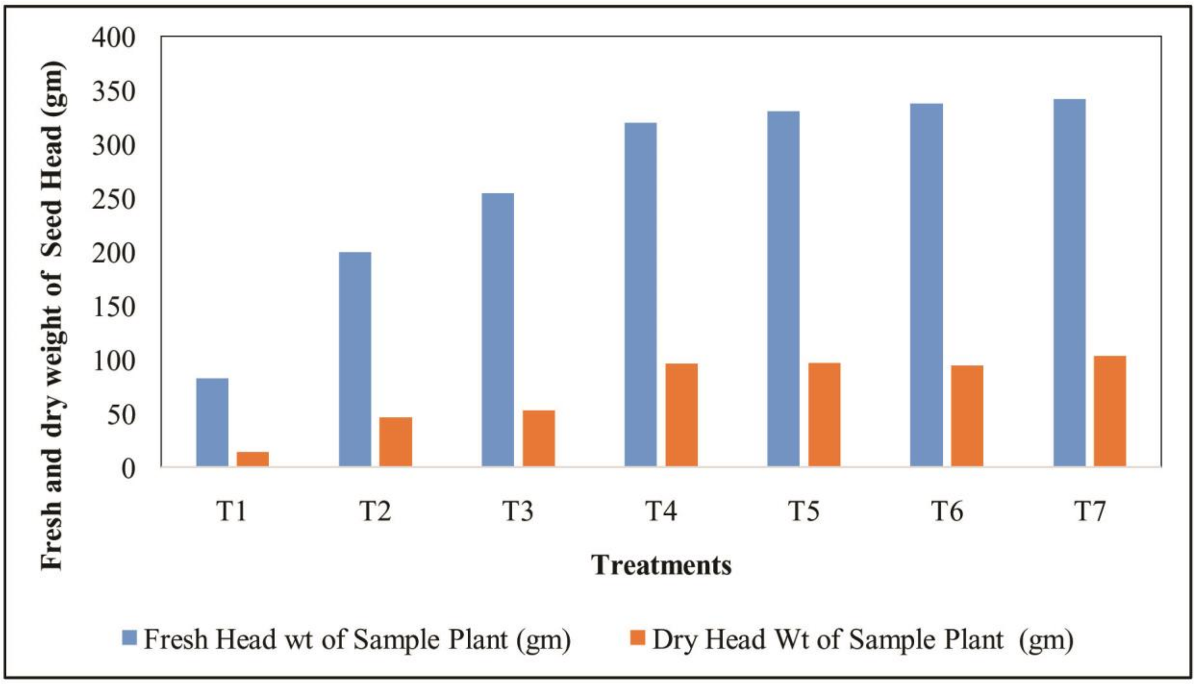


Figure 13: Effect of different organic fertilizers management on fresh and dry weight of seed per head of sunflower

Legend:

T_1 = Control (No application)
T_2= FYM @ 2 t ha^{-1}
T_3= VC @ 2 t ha^{-1}
T_4= BC @ 2 t ha^{-1}
T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}
T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}
T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.13. Fresh and dry seed number head^{-1}

In the application of different dose of organic fertilizer treatments had significant impact on the fresh and dried seed number head^{-1} (Figure 14). The result revealed during harvesting time collect data and the highest fresh seed head was recorded at T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (1457) which was almost statistically similar to T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (1447 number). While the lowest no of fresh seed head^{-1} was recorded from T_1(control) with (441). On the other hand, during harvesting time the highest number of dry seed head^{-1} was recorded at T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (293). In addition, the lowest number of dry seed head^{-1} was recorded from T_1 (196) *i.e*., control.

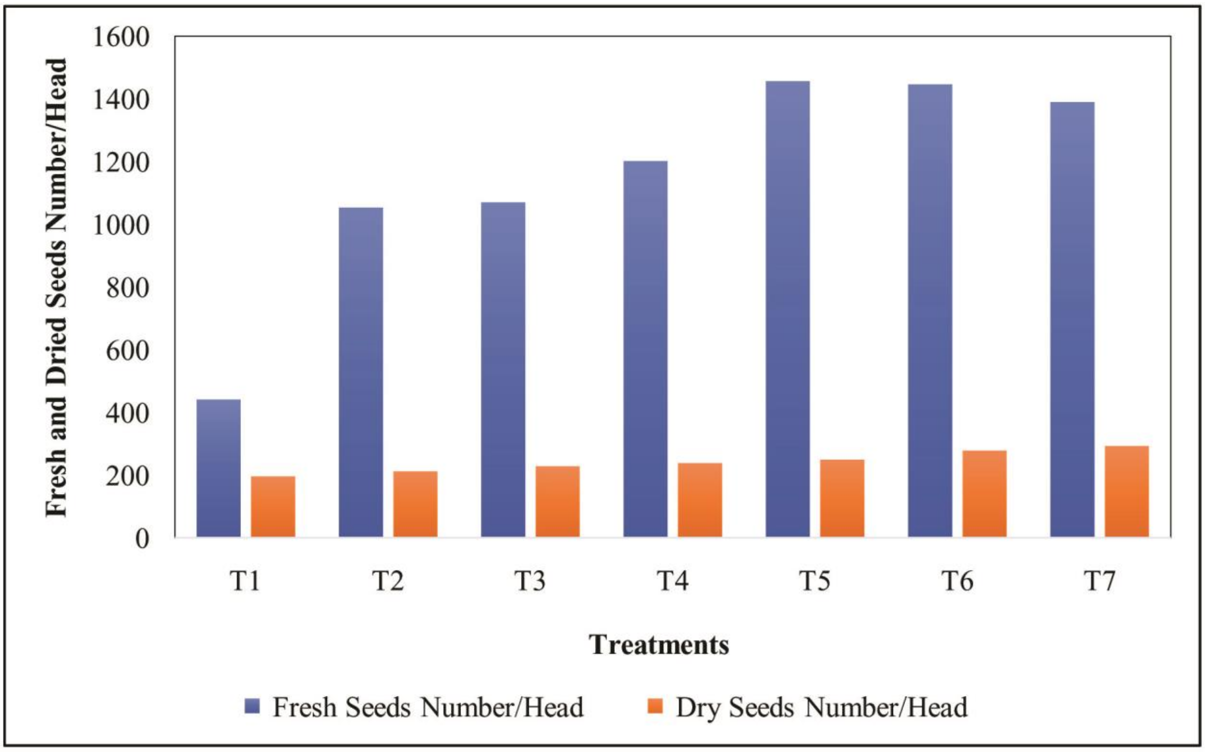


Figure 14: Effect of different organic fertilizers management on fresh and dry seed number head of sunflower

Legend:

T_1 = Control (No application)
T_2= FYM @ 2 t ha^{-1}
T_3= VC @ 2 t ha^{-1}
T_4= BC @ 2 t ha^{-1}
T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}
T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}
T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

Similar findings were observed by Solangi *et al*. (2015) shown that the fresh seeds head^{-1} was highest (1650.91), in the use of integrated nutritional levels *i.e.*, 6 t ha^{-1} poultry manure + 75% biochar fertilizers. Moreover, the lowest seeds head^{-1} observed under the treatments control and excess treatment of poultry manure with biochar. And they suggested that the combined use of biochar with FYM resulted in a greater seed index, significant increased in plant height, head size and number of seeds per head of sunflower.

4.14. Weight of seeds head^{-1}

In the application of different organic fertilizer managements had significant influenced on weight of seeds head^{-1} in sunflower plants. The highest weight of seeds head^{-1} was recorded on T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) (45.53 g), which was statistically similar with T_5 (FYM

@ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) with (45.50 g), while the lowest weight of seeds head^{-1} was recorded from T_1 (16.00 g) i.e., at control treatment (Table 6).

4. 15. 1000-Seeds weight (g)

Fertilizer management had significant effect on the 1000 seed weight of sunflower shown in the Table 6. The highest 1000 seed weight (85.67 g) was obtained when the plot treated in T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) treatment which is statistically similar with T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha-^{1}) and T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (85.40 g) and (85.67 g) respectively. While the lowest 1000 seed weight (26.33 g) was obtained when the plot treated in T_1 (control) treatment (Table 6). Al-Tawaha *et al.* (2002) concluded that the higher 1000 grin weight. Seed weight could have been due to higher rates of photosynthesis and photosynthates partitioning from source to sink (to the grains). This higher photosynthesis rate and photosynthesis partitioning might have resulted from the balanced supply of essential nutrients from both organic and inorganic sources. Subhan *et al.* (2017) and Rehman *et al.* (2008) also recorded highest thousand seed weight by the application of FYM along with chemical fertilizers. The results of the study strongly supported by Tahir *et al.* (2011) & Hossain *et al.* (2002) who reported that grain yield was significantly increased by the application of organic matter along with fertilizers.

Table 6: Effect of organic fertilizers on weight of seeds head^{-1}(g), 1000 seed weight (g), head weight (t ha^{-1}), stover weight (t ha^{-1}) of sunflower

Treatment	Wt. of seeds head^{-1}(g)	1000 Seed wt (g)	Stover yield (t ha^{-1})
T_1	16.00^{d}	26.33^{d}	1.97^{d}
T_2	30.50^{cd}	73.00^{c}	2.9^{c}
T_3	31.03^{c}	74.00^{b}	3.30^{b}
T_4	30.68^{cd}	74.20^{b}	3.15^{b}
T_5	45.50^{a}	85.65^{a}	4.81^{a}
T_6	45.40^{a}	83.40^{b}	4.49^{a}
T_7	45.53^{a}	85.67^{a}	4.36^{a}
LS	**	**	Ns
CV %	25.61	14.57	27.07
LSD	16.65	20.28	1.35

In a column, figure bearing same, or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test. ** = Significant at 1% level of probability*= Significant at 5% level of probability. LS= Level of significance; CV= Co-efficient of variance LSD= Least Significant Difference. NS= Not significant

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

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

Stover yield varied with the different levels of organic fertilizer. Stover yield was highest (4.81 t ha^{-1}) at treatment T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}). Next T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) treatments resulted stover yield (t ha^{-1}) with (4.49 and 4.36 t ha^{-1}). The lowest stover yield (1.97 t ha^{-1}) was found in T_1 treatment (Table 6). Those of Tahir *et al.* (2011) supported these results and Sarwar *et al.* (2016) who reported that stover yield of sunflower was significantly increased by the application of organic matters along with inorganic fertilizers. All result shown in (Table 6).

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

Biological yield varied significant at different levels of treatment. Biological yield was distinctly highest (8.07 t ha^{-1}) at treatment T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and showed non significant with T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) and T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (8.00 and 8.05 t ha^{-1}) biological yield. While the lowest biological yield (3.69 t ha^{-1}) was found in T_1 (control). All result shown in (Figure 15). Biological yield indicates the total dry mater produced by the plants during its life cycle organic manures are an excellent source for multi nutrient supply to crop plants, although in a variable manner are depending on their

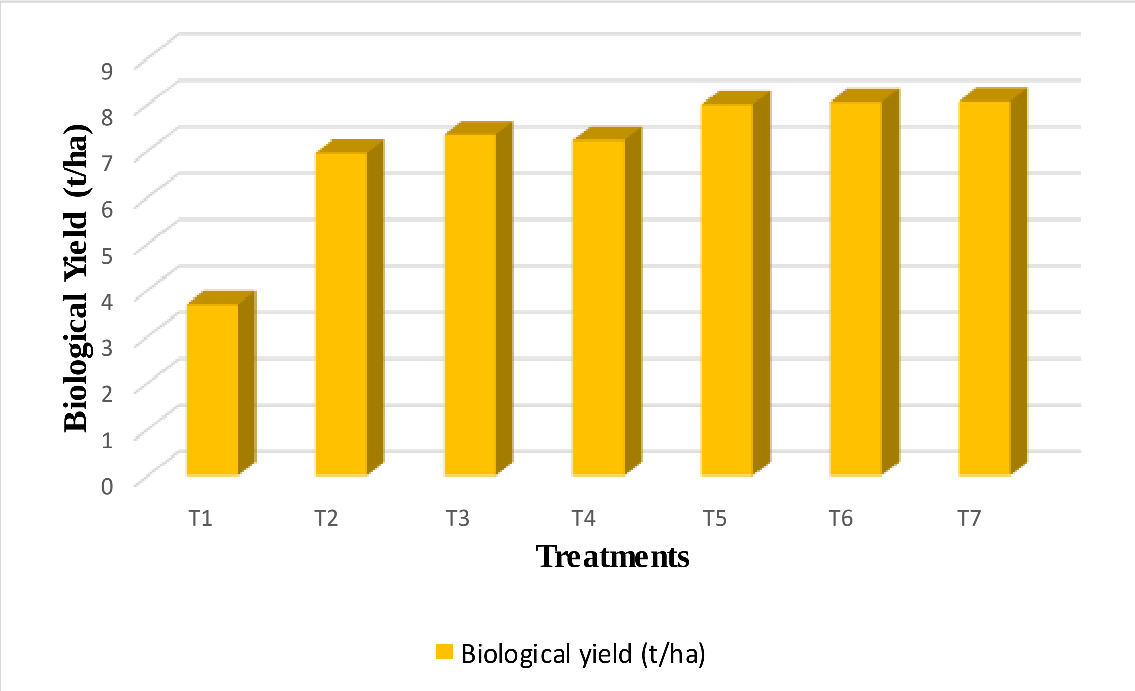


Figure 15: Effect of different organic fertilizer treatments on Biological yield of sunflower

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

type and quality (Ahmad *et al*., 2008). Channabasanagowda *et al*. (2008) reported that the high biological yield may be due to fact that the organic manures supply direct available nutrients such as nitrogen to the plant and the organic manures improve the proportion of water stable aggregates of the soil. Jala-Abadi *et al*. (2012) reported that the superiority of mixed organic manure may be attributed to balanced and gradual release of plant nutrients and increased nutrient uptake to support growth consequently increased the biological yield of different crops. The findings of our study were in line with those reported by Subhan *et al*. (2017) & Tahir *et al*. (2011) who concluded that the organic matter along with the recommended dose of synthetic fertilizers significantly affected the biological yield of the plant. Biological yield indicates the total dry matter produced by plants during its life cycle. Mukhtiar *et al*. (2018) reported that Farmyard manure were also found better compared to legume residue but were found less important in improving wheat quality compared to poultry and sheep manure.

4.18. Harvest index (%)

Effect of different treatments exerted significant variation on harvest index. The highest harvest index (47%) was recorded from treatment T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and the lowest harvest index was recorded from (18 %) from T_1 (Control). Sarma *et al*. (2018) reported that biochar introduction into the fertility program of sunflower with organic fertilizers would be a better option to uphold crop productivity & sequester higher soil organic carbon (SOC) compared to vermicompost. Subhan *et al.* (2017) reported the highest harvest index (%) by the application of manures along with inorganic fertilizers.

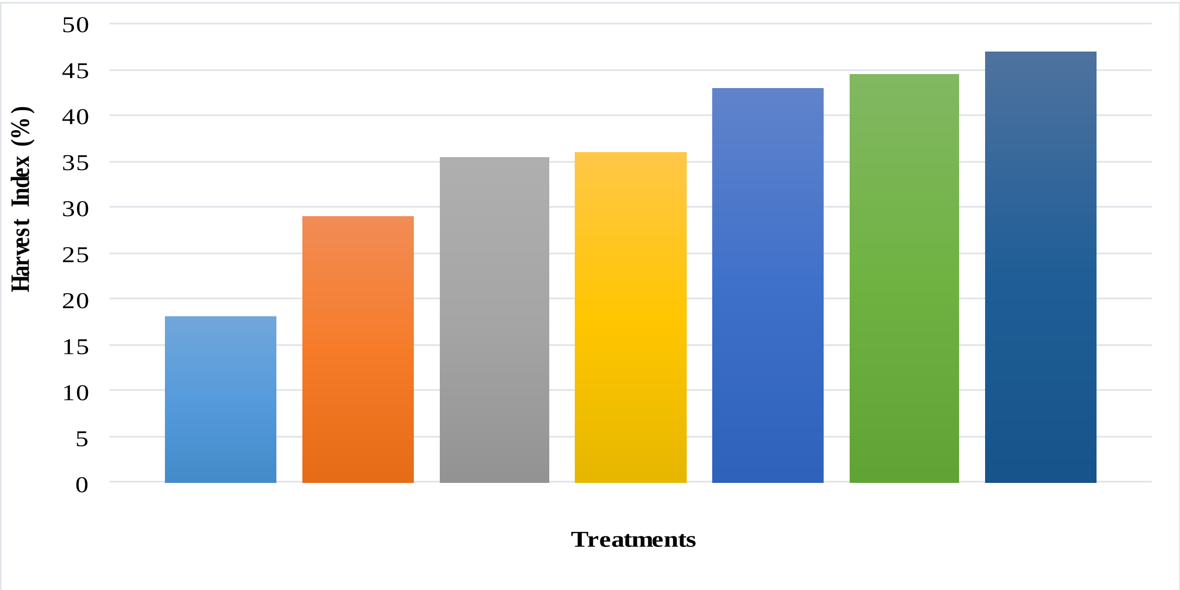


Figure 16: Effect of different organic fertilizer management on harvest index (%) of sunflower

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

4.19. Water holding capacity (%)

Effect of different organic fertilizer treatments exerted significant variation on the water holding capacity of the soil. Results showed that treatment T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) showed the highest water holding capacity *i.e.*, 92% of the soil. The second highest performance showed by T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with 87 % of the water holding capacity of the soil. While very poor performance showed by control treatment with only 11%. Besides, before applying organic fertilizer treatments, the water holding capacity of the soil was between (11.0-13.5) %. All the result showed in (Figure 17).

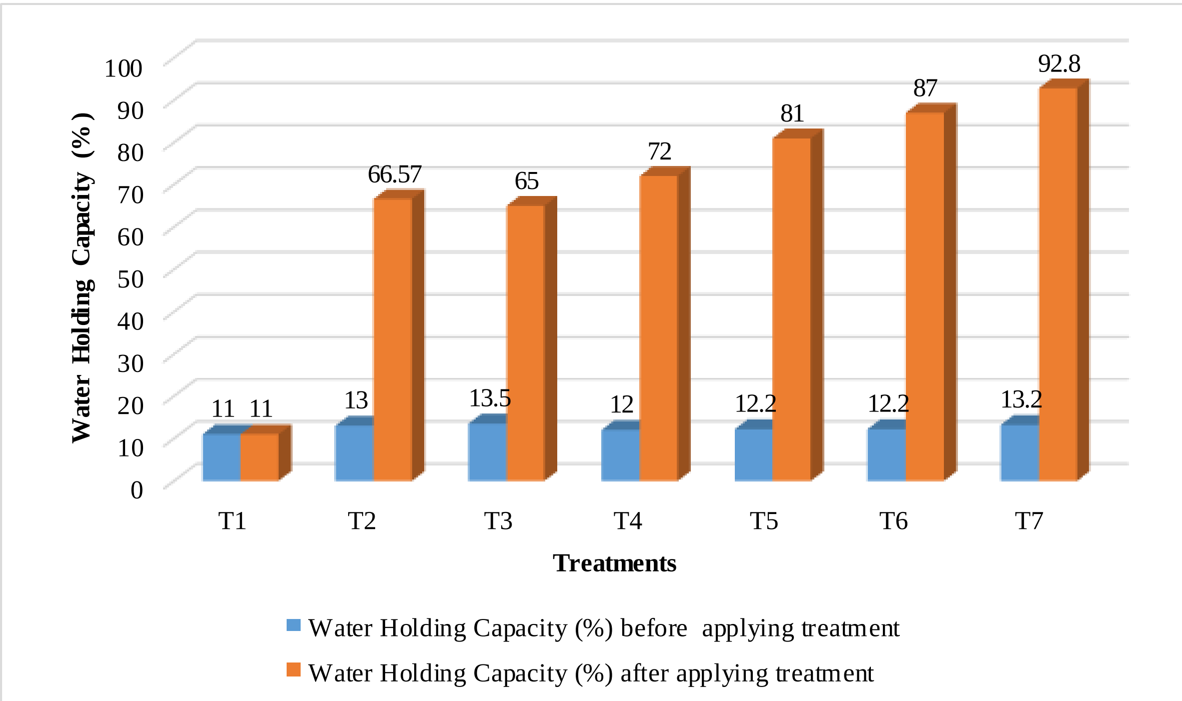


Figure 17: Effect of different organic fertilizer treatments on water holding capacity of soil

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

The use of biochar with vermicompost as a soil amendment has been suggested to increase water holding capacity exist in terms of the effectiveness of biochar in increasing a soil's water holding capacity (Yu *et al*., 2018). Therefore, to promote the use of biochar with vermicompost soil amendment, it is important to understand the mechanism of biochar-amended water retention, to characterize the effects of feedstock, biochar production, soil types, and mixtures, and to quantify these effects on sunflower growth and yield (Singh *et al*., 2020).

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

Fertilizer management had significant effect on the seed yield of sunflower shown in the (Figure 18). The highest seed yield (3.42 t ha^{-1}) was obtained when the plot treated in T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and the lowest seed yield (0.78 t ha^{-1}) was obtained when the plot treated in T_1 *i.e.,* control treatment. Treatment T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) and T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) had seed yield (t ha^{-1}) (3.20 t ha^{-1} and 3.11 t ha^{-1}). Improvement of yield components such as number of seeds $head^{-1}$ and flower head diameter in these treatments ultimately resulted in high yield of seeds. It is well recognized that crop productivity depends on adequate plant nutrients and organic matter content of the soil. Organic manure plays an important role in improving physical, chemical and biological properties of the soil. Organic manures are content low concentration of plant nutrients and they have a slow acting nature, organic manure alone may fail to tend the high nutritional requirements of crops (Hossain *et al.*, 2002). Continuous additions of the manures to the soil increase its organic matter content year after year, improving physical and chemical soil properties. This improvement is due to providing a suitable soil structure, increasing soil cation exchange capacity, and increasing the quantity and availability of plant nutrients in addition to furnishing microbial activities. It has been revealed that a sunflower hybrid gave a higher yield from a combination of organic manures with chemical fertilizers (Munir *et al*., 2007).

Similar findings was observed by (Singh *et al.*, 2020) and get a suggestion that a positive effect of combined use of biochar and FYM on sunflower yield. They further observed that integrated use of biochar along with FYM resulted in greater seed index value, a significant increase in plant height, head size, number of seeds, and overall yields per unit area. Ali Reza Safahani *et al*. (2021) reported that sunflower Seed yield ranged from 1.78 to 4.95 t ha^{-1} and it was increased by the biochar application (+9% and +7% in $B_{2.5}$ and B_5, respectively). The application of biochar and vermicompost together has a positive effect to the growth characteristics of sunflowers and will be beneficial in obtaining the highest quality, healthy seed and oil yields as reported by (Takaragawa *et al*., 2020 & Volkan Gül *et al*., 2021).

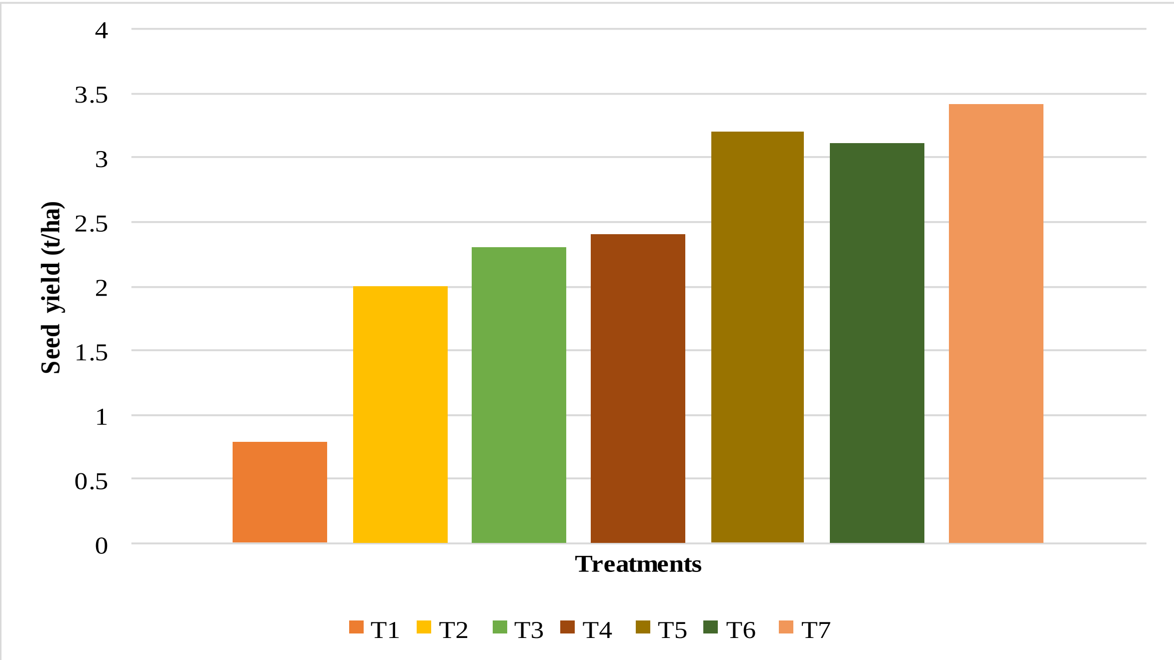


Figure 18: Effect of different organic fertilizer management on seed yield (t ha^{-1}) of sunflower

Legend:

T_1 = Control (No application)

T_2= FYM @ 2 t ha^{-1}

T_3= VC @ 2 t ha^{-1}

T_4= BC @ 2 t ha^{-1}

T_5= FYM @ 1 ha^{-1}+ VC @ 1 t ha^{-1}

T_6= FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

T_7= VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the agronomy research field, HSTU, Dinajpur, during December 2021 to April 2022 to assess the effect of organic fertilizers on the growth and yield of sunflower. The experiment consisted with one factor namely T_1= Control (No application), T_2= FYM @ 2 t ha^{-1}, T_3= VC @ 2 t ha^{-1}, T_4= BC @ 2 t ha^{-1}, T_5= FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}, T_6= FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}, T_7= VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}.

The planting material of the experiment was **BARI Surjomukhi-2** sunflower seed. The experiment was laid out in a randomized complete block design (RCBD). There were seven (7) treatment combinations, each treatment was replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the number of plots was 3 × 7 = 21. The unit plot size was 10 m^2 (4m × 2.5m) *i.e.*, 4 m long and 2.5 m wide. Irrigation and drainage channel was made by maintaining 50 cm^2 wide. By maintaining 30 cm between block to block and 25 cm between plot to plot wide and 25 cm depth plot for the experimental plot. The treatments were divided into replication wise. For replication-**I** combinations were R_1T_1, R_1T_2, R_1T_3, R_1T_4, R_1T_5, R_1T_6, R_1T_7. Replication **II**, R_2T_1, R_2T_2, R_2T_3, R_2T_4, R_2T_5, R_2T_6, R_2T_7 and replication **III**, R_3T_1, R_3T_2, R_3T_3, R_3T_4, R_3T_5, R_3T_6, R_3T_7. The recommended doses of urea, =TSP, MoP, were 80 kg, 40 kg, and 40 K_2O kg ha^{-1} respectively. The recommended dose of treatments *i.e.*, farmyard manure, vermicompost and biochar was separately as 2 $tonha^{-1}$ and the combination of FYM+VC, FYM+BC and VC+BC was 1 ton ha^{-1}. Farmyard manure used 3 plots, vermicompost used 3 plots, and biochar used 3 plots as a single treatment. While (Farmyard manure + vermicompost) combination used 3 plots (Farmyard manure + biochar) combination used 3 plots, and (Vermicompost + biochar) combination used 3 plots. In addition, 3 plots were used as control treatment.

After completion of the plot, the seeds were sown on 27^{th} December 2021. The crop was harvested at maturity on after about 100 days of sowing. The overall growth and yield were recorded for each plot from randomly selected 15 plants. Parameters like plant height, stem diameter, number of leaves $plant^{-1}$, fresh weight of leaves, dry weight of leaves, flower head diameter, number of seeds $head^{-1}$, number of dried seeds $head^{-1}$, weight of seeds $head^{-1}$, 1000 seed weight, leaf area index, head weight $plot^{-1}$, stover yield, biological yield, harvest index, water holding capacity, and seeds yield were influenced by organic fertilizers.

Plant height results of sunflower at different growth stages revealed that at 25, 50, 70, 90 DAS, and during harvesting time. The tallest plant height was recorded during harvesting time, from treatment T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) at (181.00 cm); from treatment T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with 153.00 cm. While the shortest plant height was recorded from T_1 (control) at (86.33 cm) respectively. Stem diameter at 25, 50, 70, 90 DAS, and at harvesting the highest stem diameter obtained from T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (11.7 cm). At 50 DAS, the highest stem diameter obtained from T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) with (6.8 cm). At 70 DAS the maximum stem diameter obtained from both T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (9.33 cm). While the lowest stem diameter (0.4 cm, 0.72 cm, 2.5 cm, 3.6 cm, and 3.7 cm, respectively) was obtained from T_1 (control) with different treatments.

Leaves number $plant^{-1}$ varied significantly at 25, 50, 70, 90 DAS, and at harvest for different organic fertilizer and their combination treatments. At 25 the highest leaves number $plant^{-1}$ (19.7) was recorded from T_5 T_6 T_7 which was similar result and that's why not significant and the lowest leaves number $plant^{-1}$ (8.7) was obtained from T_1(control). At 50 DAS, the highest number of leaves was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (39.7) and the lowest number of leaves was obtained from T_1 (23.3) at control. At 70 DAS, the highest number of leaves was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (43.7), and the lowest number of leaves obtained from T_1 (26) at control treatment. At 90 DAS the second highest leaves number was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (45 number), and the lowest number of leaves obtained from T_1 (26.2) at control treatment. At harvesting time the maximum number of leaves was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (48.7), and the lowest number of leaves was obtained from T_1 (control).

Different organic fertilizer treatments showed a significant variation for the fresh weight of leaves $plant^{-1}$ on different growth stages. The results revealed that at 25 DAS, the highest fresh of leaves $plant^{-1}$ (3.0 g) recorded at T_7. At 50 DAS the highest fresh wt. of leaves plant-^{1} (9.5 g) recorded at T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}). At 70 DAS, the highest fresh wt. of leaves $plant^{-1}$ (12.4 g) recorded at T_5 (FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}) and at 90 DAS, the highest fresh weight. of leaves $plant^{-1}$ (12.5 g) were recorded from treatment T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}), while the lowest fresh wt. of plants at (1.13 g, 1.52 g, 4.15 g and 4.9 g, respectively) were recorded from treatment T_1 (control). Dry weight of leaves $plant^{-1}$ showed significant variation with organic fertilizers. The results revealed that at 25, 50, 70 and 90 DAS the highest dry wt. of leaves (0.583 g) recorded at T_6, (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1})

(2.45 g) recorded at T_5, (2.92 g) recorded at T_5(FYM @ 1 t ha^{-1}+ VC @ 1 t ha^{-1}). and (3.15 g) recorded at T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}). While the lowest dry wt. of leaves at 25 and 50 DAS, (0.182 g, 1.05 g) were recorded at T_1 (Control). At 70 DAS, (1.203 g) was recorded at T_2 (FYM @ 2 t ha^{-1}). And (2.26 g) at 90 DAS recorded from T_3 (VC @ 2 t ha^{-1}).

Different fertilizer managements showed a significant variation on above ground fresh weight $plant^{-1}$ for all growth stages. The results revealed that at 25 the highest fresh weight of plants (6.8 g) at T_5 (FYM @ 1t ha^{-1}+ VC @ 1 t ha^{-1}), at 50 DAS, time the highest fresh weight of plants (26.7 g), at T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}). At 70, 90 DAS and at harvesting time the highest fresh weight of plants (40.30g, 84.33 g and 97.8 g respectively) were recorded from treatment T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}). While the lowest fresh wt. of plants at (3.64 g) were recorded from treatment T_1 (control) at 25 DAS, Then T_4 showed that second lowest fresh wt. of plants (4.0g) at 25 DAS. Second highest fresh weight of plants shown at T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}). at 70, 90 DAS, and at harvesting time was the lowest weight recorded (21.7 g, 39.9 g, 44.33 g respectively) T_1 (Control).

Different organic fertilizer managements showed a significant variation on dry weight plant for all growth stages. The results revealed that at 25, 50, 70 and 90 DAS and harvesting time the highest dry weight of plants (1.6 g) at T_3 (VC @ 2 t ha^{-1}), (14.0 g, 15.0 g, 32.4 g, and 45.95 g respectively) observed at maximum dry weight of plants observed at T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) shown in (Figure 10). Then T_5 showed that lowest dry weight of plants (0.7 g) at 25 DAS. At 50 the lowest dry wt. of plants (3.4 g) at T_4 (BC @ 2 t ha^{-1}), At 70 DAS, 90 DAS, and at harvesting the lowest dry wt. of plants (4.3 g, and 4.55 g and 4.89 respectively) recorded in T_1 (control).

Different organic fertilizer managements had significant influenced on leaf length of sunflower at all the growth stages. The results revealed that at 25 DAS, the highest leaf length (22.55 cm) was recorded from treatment T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) while the lowest leaf length recorded from T_1 (8.80 cm) in control, which is statistically dissimilar with other treatments. At 50 DAS the highest leaf length recorded from T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) with (36.26 cm), and from T_7 (BC @ 1 ha^{-1} + FYM @ 1 t ha^{-1}) with (36.25 mm) while the lowest leaf length recorded from T_1 (13.07 cm) respectively. Then the results revealed that at 70 DAS the highest leaf length recorded from T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) with (42.43 mm), which was statistically dissimilar with T_2, T_4, T_5, and T_6 (18.99, 33.59, 35.73, 38.20, 40.03, and 40.19 mm, respectively), while the lowest leaf length was obtained from T_1 (18.99 mm). At 90 DAS, the highest leaf length was recorded from treatment T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}) while the lowest leaf length was recorded from T_1 (22.76 mm).

Different organic fertilizer managements had significant influenced on the leaf area index of sunflower at all the growth stages. The results revealed that at 25 DAS, the highest leaf area index (1.16.) was recorded from treatment T_7 (BC @ 1 t ha^{-1} + FYM @ 1 t ha^{-1}). While the lowest leaf area index was recorded from T_1 (0.24). At 50 DAS, the highest leaf length width ratio was recorded from T_6 (1.23) (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) while the lowest leaf area index was recorded from T_1 (control) (0.64), respectively which is statistically non significant with other treatments. Then, the results revealed that at 70 DAS, the highest leaf area index was recorded from T_5 (1.36) (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) and the lowest leaf width ratio was recorded from T_1 (Control). At 90 DAS, the highest leaf area index was recorded from T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) andT_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) (1.40 and 1.40), respectively. However, the lowest leaf area index was recorded from T_1 (0.68).

Chlorophyll content was an important parameter in the production. It was varied from treatment to treatments. It was found to be significant statistically at 25, 50, 70, and 90 DAS shown in. At 25 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (90.60 %) and the lowest result was recorded T_1 (64.64 %) *i.e.,* at control treatment. At 50 DAS, the highest result was recorded from T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (109.03 %) and the lowest was T_1 (70.83 %). At 70 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (193.67 %) and the lowest was T_1 (81.67 %). At 90 DAS, the highest result was recorded from T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (165.67 %), also T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t h^{-1}), showed the close at T_7 the lowest was T_1 (164.67%).

Organic fertilizer and treatments had a significant impact on the head diameter in different growth stages. The result showed that at T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) treatment, the highest flower head diameter observed at harvesting stage with (30 cm) shown in. In contrast, the lowest result was recorded at 70 DAS with (23.3 cm). At T_6 (FYM @ 1 t ha^{-1}+ BC @ 1 ha^{-1}) treatment, the highest flower head diameter was seen at harvesting stage (29 cm) and the lowest result was recorded (20 cm) at 70 DAS. Very lowest performance was shown by T_1 treatment *i.e*., at control for all stages. After harvesting, the highest fresh weight was recorded from T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (342 g). After that, gradually decreased at T_6, T_5, T_4, T_3, T_2 and T_1 above this the weight respectively (338, 330, 320, 255, 200, and 82) g respectively. The dry weight of the flower head was highest T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (104 g) and then decreased significantly at T_5, T_4, T_6, T_3, T_2, T_1 with (97, 96, 95, 53, 46 and 15) g respectively.

Organic fertilizer treatments had significant impact on the fresh and dried seed number $head^{-1}$. The result revealed during harvesting time collect data and the highest fresh seed $head^{-1}$ was recorded at T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) with (1457 number) which is almost statistically similar to T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (1447 number). While the lowest no of fresh seed $head^{-1}$ was recorded from T_1 (control) with (441 number). On the other hand, during harvesting time the highest number of dry seed $head^{-1}$ was recorded at T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (293 number). In addition, the lowest no of dry seed $head^{-1}$ was recorded from T_1 (196) (Control).

Different organic fertilizer managements had significant influenced on weight of seeds $head^{-1}$ in sunflower plants. The highest weight of seeds $head^{-1}$ was recorded on T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) (45.53 g), which is statistically similar with T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) with (45.50 g), while the lowest weight of seeds $head^{-1}$ was recorded from T_1 (16.00 g) at (Control).

The highest 1000 seed weight (85.67 g) was obtained when the plot treated in T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) treatment which is statistically similar with T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) with (85.40 g) and (85.67 g) respectively. While the lowest 1000 seeds weight (26.33 g) was obtained when the plot treated in T_1 (control). Stover yield varied with the different levels of organic fertilizer. Stover yield was highest (4.81 t ha^{-1}) at treatment T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}). Next T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) and T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) treatments resulted stover yield (t ha^{-1}) with (4.49 and 4.36 t ha^{-1}). The lowest stover yield (1.97 t ha^{-1}) was found in T_1 treatment Control. Biological yield was distinctly highest (8.07 t ha^{-1}) at treatment T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) and showed nonsignificant with T_5 (FYM @ 1 t ha^{-1} + VC @ 1 t ha^{-1}) and T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with (8.00 and 8.05 t ha^{-1}) biological yield. While the lowest biological yield (3.69 t ha^{-1}) was found in T_1 (control) Effect of different fertilizer management exerted significant variation on harvest index. The highest harvest index (47%) was recorded from treatment T7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) and the lowest harvest index was recorded from (18 %) from T1 (Control).

Effect of different organic fertilizer treatments exerted significant variation on the water holding capacity of the soil. Results showed that treatment T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) showed the highest water holding capacity i.e., 92% of the soil. The second highest performance showed by T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) with 87 % of the water holding capacity of the soil. While very poor performance showed by control treatment with only 11%.

The effect of different organic fertilizer treatments showed a highly significant variation in the water holding capacity of the soil. Results showed that treatment T_7 (VC @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) and T_6 (FYM @ 1 t ha^{-1} + BC @ 1 t ha^{-1}) showed the highest water holding capacity *i.e.,* 92% and 87% respectively. While very poor performance showed by control treatment with only 11%. Besides, before applying organic fertilizer treatments, the water holding capacity of the soil was between (11.0-13.5) %.

From the experimental results, the highest seed yield was observed (3.42 t ha^{-1}) when the plot treated with T_7 (VC @ 1 t ha^{-1}+ BC @ 1 t ha^{-1}) and the lowest seed yield (0.78 t ha^{-1}) with control treatment. Therefore, for efficient sunflower production application of vermicompost and biochar organic manure are beneficial. Therefore, it is possible to reduce the use of chemical fertilizers by combined use of organic fertilizers without significant yield loss in sunflower. Cultivation of **BARI Surjamukhi-2** sunflower variety with different organic fertilizer doses are very important for obtaining a higher yield of sunflower in the acidic soil of the HSTU campus as well as also for Old Himalayan Piedmont Plain (AEZ-1) soils.

REFERENCES

Abd-Elhamied, A. and K. Fouda. 2018. Influence of Application Methods of Biochar and Poultry Manure on Yield and Nutrients Uptake of Sunflower Plant Fertilized with Different Nitrogen Rates. J. Soil Sci. Agri. Eng. 9(1): 47-53.

Abd–Elrahman, S. H., H. S. Saudy, D. A. A. El–Fattahand and F. A. E. Hashem. 2022. Effect of irrigation water and organic fertilizer on reducing nitrate accumulation and boosting lettuce productivity. J. Soil Sci. Plant Nutri. 3(1):1-12.

Adeleke, B.S. and O.O. Babalola. 2020. Oilseed crop sunflower (Helianthus annuus) as a source of food: Nutritional and health benefits. Food Science and Nutrition. 8(9): 1-19.

Ahmad, R. and N. Jabeen. 2009. Demonstration of growth improvement in sunflower (*Helianthus annus* L.) by the use of organic fertilizers under saline conditions. Pakistan J. Bot. 41(3): 1373-1384.

Akbari, P., A. Ghalav, A. M. Sanavy, M. A. Alikhani and S. S. Kalkhoran. 2011. Comparison of different nutritional levels and the effect of plant growth promoting rhizobacteria (PGPR) on the grain yield and quality of sunflower. Australian J. Crop Sci. 5(12): 1570-1576.

Alburquerque, J. A., J. M. Calero, V. Barrón, J. Torrent, M. C. del Campillo, A Gallardo and R. Villar. 2014. Effects of biochars produced from different feedstocks on soil properties and sunflower growth. J. Plant Nut. Soil Sci. 177(1): 16-25.

Ali Reza Safahani, L., M. Roberto and R. Emanuele. 2021. Contribution of biochar and arbuscular mycorrhizal fungi to sustainable cultivation of sunflower under semi-arid environment. Field Crops Res. 273 (1): 1-18.

Al-Tawaha, A. M., M. A. Turk, K. D. Lee, W. Z. Zheng, M. Ababneh, G. Abebe and I. W. Musallam. 2005. Impact of fertilizer and herbicide application on performance of ten barley genotypes grown in Northeastern part of Jordan. Intern. J. Agr. Bio. 7(2): 162-166.

Alzamel N. M., E. M. Taha, A. A. Bakr, and N. Loutfy. 2022. Effect of Organic and Inorganic Fertilizers on Soil Properties, Growth Yield, and Physiochemical Properties of Sunflower Seeds and Oils. Sustainability. 14(19): 1-18.

BBS. 2020. Yearbook of Agricultural Statistics. Statistics and Informatics Division (SID). Ministry of Planning Government of the People's Republic of Bangladesh. Page 263.

Bhardwaj, D., M. W. Ansari, R. K. Sahoo and N. Tuteja. 2014. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microbial Cell Factories. 13(66): 1-10.

Byra Reddy, K., D. S. Uppar, B. S. Vyakaranahal, S. M. Hiremath, R. Hunje and H. I. Nadaf. 2018. Effect of Integrated Nutrient Management on Sunflower Hybrid (KBSH-I) Seed Production. Karnataka J. Agric. Sci. 21(2):171-175.

Channabasanagowda, N. K., B. Patil, B. N. Patil, J. S. Awaknavar, B. T. Ninganurn and R. Hunje. 2008. Effect of organic manures on growth, seed yield and quality of wheat. Karnataka J. Agric. Sci. 21(3):366-368.

De B, Sinha. 2014. Oil and protein yield of rapeseed (*Brassica campestris* L.) as influenced by integrated nutrient management. SAARC J. Agr. 10(2): 41–9.

De Jesus, K. N., R. S. C. Menezes, R. N. De Araujo Filho, E. V. De Sá Barretto Sampaio, A. C. D. Antonino and D. C. Primo. 2020. Maize and sunflower yields and soil changes after five years of organic fertilization in the semi-arid region of Paraiba, Brazil. Arid Land Res. Man. 34(4): 460-473.

Devi, K. N., A. K. Vyas, M. S. Singh and N.G. Singh. 2011. Effect of bioregulators on growth, yield and chemical constituents of soybean (*Glycine max)*. J. Agril Sci. 3(4): 151.

FAO. A Statistical Year Book. 2019. Per capita oil crop production (2000-2010). FEEDING THE WORLD. pp: 134.

Gondim, R. S., C. R. Muniz, C. E. P. Lima and C. L. A. D. Santos. 2018. Explaining the water-holding capacity of biochar by scanning electron microscope images. Revista Caatinga. 31(2018): 972-979.

Gül, V., F. Çoban and E. Öztürk. 2021. Effect of liquid and solid vermicompost applications on growth and yield of sunflower (*Helianthus annuus* L.). Alinteri. J. Agric. Sci. 36(1): 55-60.

Gyewali, B., B. Maharjan, G. Rana, R. Pandey, R. Pathak and P. R. Poudel. 2020. Effect of different organic manures on growth, yield, and quality of radish (*Raphanus Sativus*). SAARC J. Agr. 18(2): 101-114.

Hossain, S. and F. Akter. 2020. Effects of Trichoderma-enriched biofertilizer enriched biofertoilizer and farmyard manure on the growth and yield of sunflower (*Helianthus annuus*). Dhaka Univ. J. Biol. Sci. 29(1): 1-8.

Hossain, S. M. A., A. M. A. Kamal, M. R. Islam and M. A. Mannan. 2002. Effect of different levels of chemical and organic fertilizers on growth, yield and protein content of wheat. J. Bio. Sci. 2(5): 304-306.

Islam, M.S., M. Z. Hossain and M.B. Sikder.2019. Farmers' adaptation strategies to drought and determinants in barind tratct, Bangladesh. SAARC J. Agric. 17(1): 161-174.

Jabborova, D., H. Ma., S. D.B. Kimura and S. Wirth. 2021. Impacts of biochar on basil (*Ocimum basilicum*) growth, root morphological traits, plant biochemical and physiological properties and soil enzymatic activities. Scientia Horticulturae. 290(2021): 11-18.

Janmohammadi, M., A. Seifi, M. Pasandi and N. Sabaghnia. 2016. The impact of organic manure and nano-inorganic fertilizers on the growth, yield and oil content of sunflowers under well-watered conditions. Biologija, 62(4):233-238.

Keshta, M. M., T. Y. Rizk and E. T. Abdou. 2008. Sunflower response to mineral nitrogen, organic and bio-fertilizers under two different levels of salinity. In Proceedings of the 17th International Sunflower Conference, Cordoba, Spain, June. 8(12): 451-454.

Khan, M. A., V. Sharma and R. K. Shukla. 2016. Response of sunflower (*Helianthus annuus* L.) to organic manure and bio-fertilizer under different levels of mycorrhiza and sulphur in comparison with inorganic fertilizer. J. Crop Weed. 12(1): 81-86.

Khatun, M., M. B. Tanbir, M. A. Hossain, M Miah, S. Khandoker and M. A. Rashid. 2016. Profitability of sunflower cultivation in some selected sites of Bangladesh. Bangladesh J. Agril. Res. 41(4): 599-623.

Khodaei-joghan, A., M. Gholamhoseini, A. A. Majid, F. Habibzadeh, A. Sorooshzadeh and A. Ghalav. 2018. Response of sunflower to organic and chemical fertilizers in different drought stress conditions. Acta Agriculturae slovenica. 111(2): 271-284.

Kumar, V., P. K. Sharma, S. Kant, S. A. Rai and A. Kumar. 2018. Organic amendments influence mustard (*Brassica juncea*) growth in chromium contaminated soils. J. Phar. Phy. 7(4): 2026-2038.

Matome Mokgolo. J., J. Mzezewa and J. O. Jude Odhiambo. 2019. Poultry and cattle manure effects on sunflower performance, grain yield and selected soil properties in Limpopo Province, South Africa. South African J. Sci. 115(11/12):1-7.

Miah, M. M. A., S. M. A. Shiblee and M. A. Rashid. 2015. Economic Impacts of Oilseed Research and Development in Bangladesh. Econ papers. 38(1): 1-31.

Mokgolo, M. J., J. Mzezewa and J. J. Odhiambo. 2019. Poultry and cattle manure effects on sunflower performance, grain yield and selected soil properties in Limpopo Province, South Africa. South African J. Sci. 115(11-12): 1-7.

Muhsin, S. J., M. N. Ramadhan and A. J. Nassir. 2021. Effect of organic manure and tillage depths on sunflower (*Helianthus annuus* L.) production. Earth and Environmental Sci. 735(1): 1-9.

Mukhtiar, A., A. Waqar, M. K. Khalil, M. Tariq, S. Muhammad, A. Hussain and A. Kamal. 2018. Evaluating the potential organic manure for improving wheat yield and quality under agro-climatic conditions. Pak. Adv. Crop Sci. Tech. 6(349): 2-8.

Munir, M. A., M. A. Malik and M. F. Saleem. 2007. Impact of integration of crop manuring and nitrogen application on growth, yield and quality of spring planted sunflower (*Helianthus annuus* L.). Pak. J. Bot. 39(2): 441-445.

Nafady, N. A., M. Hashem, E. A. Hassan, H. A. Ahmed and S. A. Alamri. 2019. The combined effect of arbuscular mycorrhizae and plant-growth-promoting yeast improves sunflower defense against *Macrophomina phaseolina* diseases. Bio. Control. 138(2019): 104-108.

Onwudiwe, D. C., E. E. Elemike, I. M. Uzoh and O. O. Babalola. 2019. The role of nanotechnology in the fortification of plant nutrients and improvement of crop production. Applied Sci. 2019(9): 499-502.

Oshundiya, F. O., V. I. O. Olowe, F. A. Sowemimo and J. N. Odedina. 2014. Seed yield and quality of sunflower (*Helianthus annuus* L.) as influenced by staggered sowing and organic fertilizer application in the humid tropics. Helia. 37(61): 237-255.

Palacio-Román, S. A. and B. Agudelo-Escobar. 2020. Development of sunflower (*Helianthus annuus* L.) with application of quail manure under different irrigation sheets. Revista Cienciay Agril. 17(1):3-17.

Rasool, F. U., B. Hassan and A. Jahangir. 2013. Growth and yield of sunflower (*Helianthus annus* L.) as influenced by nitrogen, sulphur and farmyard manure under temperate conditions. SAARC J. Agr. 11(1): 81-89.

Rasool, G., A. Ullah, A. Jan, M. Waris, M. A. Tariq and Q. Ahmad. 2021. Morphological evaluation of wheat genotypes for grain yield under arid environment of Baluchistan. Pure. Applied Bio. 10(4): 1441-1449.

Rondon, M., J. Lehmann, J. Ramírez and M. Hurtado. 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. Bio. Fert. Soil. 43 (2007): 699-708.

Saeed, N., M. Hussain and M. Saleem. 2002. Interactive effect of biological sources and organic amendments on the growth and yield attributes of sunflower (*Helianthus annuus* L.). Pak. J. Agri. Sci. 39(2): 135-136.

Salmani, M. S., F. Khorsandi, J. Yasrebi and N. Karimian. 2014. Biochar effects on copper availability and uptake by sunflower in a copper contaminated calcareous soil. Intern. J. Plant Animal Envion. Sci. 4(3): 2310-2314.

Sarker U. K., M. S. Hossain, M. R. Uddin, D. Hossain, M. K. Islam and M. K. Hossain. 2021. Enhancing Sunflower Production Through the Use of Sustainable Nutrient Management in the Coastal Region of Bangladesh. J. Agro. Environ. 14(1&2):7-11.

Sarma, B., M. Farooq, N. Gogoi, B. Borkotoki, R. Kataki and A. Garg. 2018. Soil organic carbon dynamics in wheat-Green gram crop rotation amended with vermicompost and biochar in combination with inorganic fertilizers: A comparative study. J. Cleaner Pro. 201(2018): 471-480.

Sarwar, M. A., M. Tahir, A. Tanveer and M. Yaseen. 2016. Evaluating Role of Plant Growth Promoting Rhizobacteria for Improving Phosphorus use Efficiency and Productivity in Sunflower (*Helianthus annuus*). Intern. J. Agr. Bio. 18(5):882-888.

Seiler, G. J. 2007. Wild annual Helianthus anomalus and H. deserticola for improving oil content and quality in sunflower. Ind. Crops Pro. 25(2007): 95–100.

Seleiman, M. F., M. A. Alotaibi, B. A. Alhammad, B. M. Alharbi, Y. Refay and S. A. Badawy. 2020. Effects of ZnO nanoparticles and biochar of rice straw and cow manure on characteristics of contaminated soil and sunflower productivity, oil quality, and heavy metals uptake. Agron. 10(6): 1-21.

Sharma, K. and V. K. Garg. 2019. Vermicomposting of waste: Chapter 10 - Vermicomposting of Waste: A Zero-Waste Approach for Waste Management. Sustainable Resource Recovery and Zero waste Approaches. pp. 133-164.

Sharma, R. A. 1992. Efficient water use and sustainable production an and safflower through conjunctive use of organics and fertilizer. Crop Res. 5: 188-194.

Sharma, S., A. Kumar, A. P. Singh and P. Vasudevan. 2009. Earthworms and vermitechnology–A review. Dynamic soil, Dynamic plant. 3(2): 1-12.

Singh, B., B. P. Singh and A. L. Cowie. 2020. Characterization and evaluation of biochar for their application as a soil amendment. Soil Res. 48(7): 516–525.

Solangi, K. H., S. N Kazi, M. R. Luhur, A. Badarudin, A. Amiri, R. Sadri and K. H. Teng. 2015. A comprehensive review of thermo-physical properties and convective heat transfer to nanofluids. Energy. 89(2015): 1065-1086.

Subhan, A., Q. U. Khan, M. Mansoor and M. J. Khan. 2017. Effect of organic and inorganic fertilizer on the water use efficiency and yield attributes of wheat under heavy textured soil. Sarhad J. Agric. 33(4): 582-590.

Tahir, M., N. Lindeboom, M. Båga, A. Vandenberg and R. Chibbar. 2011. Composition and correlation between major seed constituents in selected lentil (*Lens culinaris*. Medik) genotypes. Canadian J. Plant Sci. 91(5): 825-835.

Takaragawa, H., S. Yabuta, K. Watanabe and Y. Kawamitsu. 2020. Effects of Application of Bagasse- and Sunflower Residue-derived Biochar to Soil on Growth and Yield of Oilseed Sunflower. Trop. Agr. Develop. 61(2020):132-139.

Thind, S. S., A. S. Sidhu, N. K. Sekhon and G. S. Hira, 2007. Integrated nutrient management for sustainable crop production in potato-sunflower sequence. J. Sust. Agri. 29(4): 173-188.

Vedpathak, M. M. and B. L. Chavan. 2016. Studies on Impact of Organic and Chemical Fertilizers on Growth and Yield of Sunflower (*Helianthus Annuus* L). J. Res. 2(10): 29-33.

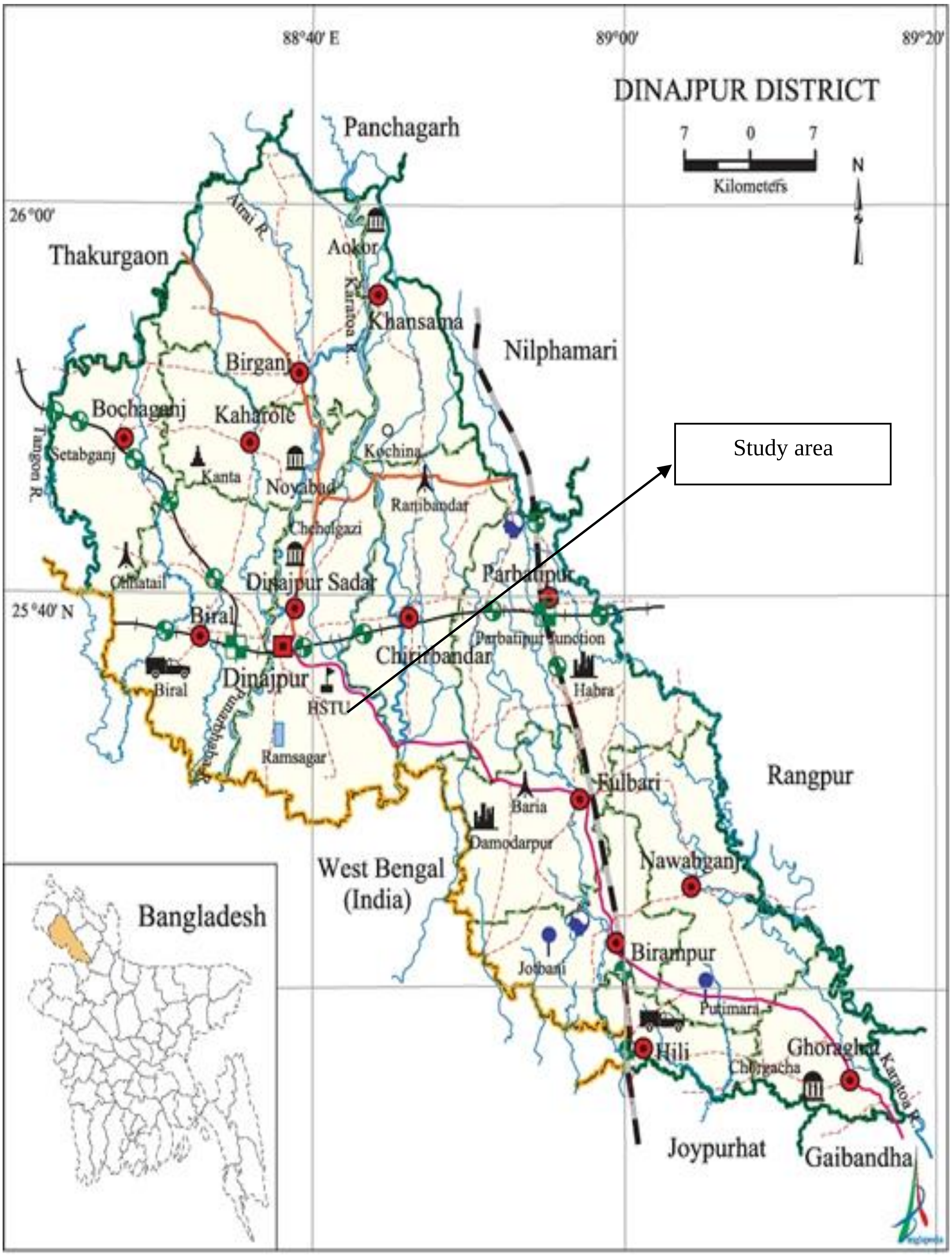
Volkan Gül., Ç. Furkan and O. Erdoğan. 2022. Effect of Liquid and Solid Vermicompost Applications on Growth and Yield of Sunflower (*Helianthus annuus* L.). Alenteri J. Agri. Sci. 36(1):55-60.

Wabekwa, J. W., D. Aminu, and Z. Dauda. 2014. Physio-morphological response of sunflower (*Helianthus annuus* L.) to poultry manure in Wamdeo, North-east Nigeria. Int. J. Adv. Agric. Res. 2(2014): 100-105.

Yu, O. Y., B. Raichle and S. Sink. 2018. Impact of biochar on the water holding capacity of loamy sand soil. Intern. J. Energy. Environ. Eng. 4(1):44-48.

APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot)



Appendix II. Experimental Photographs

Plate 1: Water Management

Plate 2: Measurement of Manures

Plate 3: Collecting data

Plate 4: Fertilizer Application

Plate 5: Measurement of plant height

Plate 6: Observed head diameter

Plate 7: Taken Chlorophyll Content of Leaves

Plate 8: Plants insect inspection

Plate 9: Field at flowering stage

Plate 10: Beautification of field

Plate 11: Harvesting