Integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* L.)

MD. ALAUDDIN

Registration no. 58

Session: 2016-2017

Thesis submitted to the University of Dhaka for the degree of Doctor of Philosophy

Department of Soil, Water and Environment

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BANGLADESH

January, 2020

DECLARATION

I hereby declare that the thesis entitled "Integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* L.)" has been composed by me and all works presented herein are of my own experimental findings. I further declare that this work has not been submitted anywhere for any academic degree, prize or scholarship and not published any where.

(MD. ALAUDDIN)
January, 2020.

This work is dedicated

to

Minu, Miftahul Zannat and my late parents.

Certificate

We have much pleasure to certify that the research work presented in this dissertation entitled "Integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* L.)" has been performed by Mr. Md. Alauddin in the research farm of charfasson Govt. college, Bhola. He accomplished all sorts of research activities under our supervision and guidance. The part of this dissertation has not been submitted to elsewhere for any degree or diploma. It is further, certified that the work presented herewith is original and very suitable for submission for the award of the degree of Ph. D.

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ACKNOWLEDGEMENT

Initially, I express my deepest sense of gratitude to the "Almighty Allah" who has gifted me ability, power, merit, intelligence and courage to conduct the research work and to submit this dissertation.

I would like to take my great privilege to express my indebtedness and deepest sense of profound gratitude to my reverend supervisor Professor Dr. Md. Khalilur Rahman and joint supervisor Professor Dr. A. H. M. Zulfiquar Ali, Department of Soil, Water and Environment, University of Dhaka for their keen, sincere and enthusiastic interest in my work. I will remain ever grateful to them for their constant comments and suggestions, scholarly guidance and valuable advice, inspiration and encouragement for the completion of the dissertation. Moreover, their excellent constructive criticisms, discussion, relentless and pains taking effort was immensely valuable times during the preparation of this manuscript for which I would like to extend my sincere respect to them.

I also express my sincere gratefulness to the Vice Chancellor, Noakhali Science and Technology University and former Chairman, Professor Dr. Md. Didar-ul-Alam, Department of Soil, Water and Environment, University of Dhaka for his valuable advice, inspiration and encouragement. I express my sincere gratefulness to the members of the academic staffs and all employees of the Department of Soil, Water and Environment, University of Dhaka for their kind help and encouragement.

I further express my sincere gratefulness to the former professor Dr. Rameswar Mandal, Department of Soil, Water and Environment, University of Dhaka for his valuable advice and encouragement.

I convey my appreciation, indebtedness, profound gratitude and ever gratefulness to Kaysar Ahamad (Dulal), Principal, Charfasson Govt. College for giving me permission, endless efforts and great sacrifice to carry out this experiment.

I also express my sincere gratefulness to the Principal Scientist & Head, Food Analysis and research laboratory, Centre for Advanced Research in Science (CARS) Md. Latiful Bari, Ph. D. for his laboratory facilities. Sincere appreciation is also due to all staff of CARS especially Sanzid bhai.

Finally, I express my heartfelt gratitude and regards to my beloved wife Mrs. Maksuda Begum, lecturer, Department of Bangla, Karim Jan Mohila Kamil Madrasha, Bhola, for her support. At last, I am showing my love and affection to my daughter Meftahul Zannat to complete this research work.

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Integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* L.)

by

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Abstract

Four field experiments were conducted separately at the Research Farm of Charfasson Govt. College, Bhola during rabi season in (2015-2016) and (2016-2016) using four rates of each of cow dung (CD), rice bran (RB), vermicompost (VC) (0.0, 2.5, 5.0, 7.5 t ha^{-1}), poultry litter (PL) (0.0,1.5, 3.0, 4.5 t ha^{-1}) and NPK (0.0, 50, 100, 150% RDF) alone and in combination on sunflower (*Helianthus annus* **L.** var. keroni-2). Sixteen treatments, in triplicate, were arranged into a completely randomized block design.

Results showed that the growth and yield attributes, composition and quality of seeds (oil and protein) of the crop increased with increasing rate of the amendments significantly ($P< 0.05$) over the control and the variation between the treatments were also significant irrespective of the sources of amendments in most of the cases. Generally, combination of the treatments showed better performance than their individual application.

Highest values of growth parameters due to application of CD, RB, PL and VC were 208.4, 196.0, 204.3, 198.4 for height (cm); 41.2, 45.5, 44.8, 45.3 for leaf number ($plant^{-1}$); 410.3, 384.4, 376.4, 381.0 for leaf area (cm^2); 12.8, 13.6, 13.6, 14.6 for LAI; 60.7, 67.3, 63.8, 72.4 for stem (g $plant^{-1}$); 12.8, 16.0, 12.7, 18.9 for root (g $plant^{-1}$); 25.3, 24.0, 21.5, 19.2 for leaf (g $plant^{-1}$); 10.0, 5.8, 8.7, 7.7 for petiole (g $plant^{-1}$); 19.3, 18.0, 32.6, 38.3 for inflorescence (g $plant^{-1}$) and 121.3, 127.7, 134.0, 153.9 for total dry matter (g $plant^{-1}$), respectively. Most of the values were recorded in combined treatments of 150% NPK with 7.5t ha^{-1} of CD, RB; 4.5t ha^{-1} of PL respectively. However, in the NPK+VC treated plants the highest dry matter yields were found in 150% NPK alone.

Concentration and uptake of NPKS measured in different parts of sunflower increased due to treatments of organic and inorganic fertilizers applied alone and in combination significantly ($P< 0.05$) with increasing level of rates irrespective of the sources of organic manures. Maximum values of NPKS concentration (%) in different organs of sunflower were 1.33, 0.33, 1.85, 0.19 for stem; 1.08, 0.38, 2.04, 0.18 for root; 3.45, 0.67, 4.12, 0.18 for leaf; 1.99, 0.62, 3.0, 0.22 for petiole; 0.73, 0.68, 2.25, 0.23 for inflorescence and 4.95, 0.94, 0.75, 0.26 for seed due to application of CD, 1.22, 0.35, 1.90, 0.18 for stem; 1.17, 0.35, 2.41, 0.16 for root; 3.98, 0.43, 4.28, 0.24 for leaf, 1.04, 0.65, 3.00, 0.22 for petiole; 2.16, 0.58, 2.21, 0.26 for inflorescence and 5.24, 0.83, 1.60, 0.47 for seed due to application of RB, 0.65, 0.42,

1.80, 0.17 for stem; 1.02, 0.54, 1.54, 0.18 for root; 4.47, 0.57, 3.14, 0.20 for leaf; 2.60, 0.64, 3.20, 0.32 for petiole; 1.30, 0.95, 2.19, 0.32 for inflorescence; 5.18, 0.86, 1.02, 0.31 for seed due to PL, 0.42, 0.23, 1.95, 0.12 for stem; 0.57, 0.33, 2.66, 0.20 for root, 2.61, 0.42, 2.77, 0.19 for leaf; 2.30, 0.65, 2.65, 0.20 for petiole; 0.76, 0.71, 2.21, 0.26 for inflorescence and 4.86, 0.69, 1.08, 0.16 for seed measured from VC treated plants, respectively. The highest concentrations of NPKS of different organs of sunflower at maturity, were found significantly ($P < 0.05$) in combined treatment of 5.0, 7.5t ha^{-1} of CD, RB, VC or 3.0 and 4.5t ha^{-1} PL with 150% NPK, respectively, in most of the cases. However, their uptake pattern also followed the same trend as in concentration and was the reflection of dry matter yield of growth attributes.

Seed yield (g $plant^{-1}$) was also recorded to be maximum in 7.5t ha^{-1} of CD (64.7), RB (46.0), 5t ha^{-1} VC (57.61) and 4.5t ha^{-1} of PL (44.4) with 100 and 50% NPK showing an appreciable variation among the treatments of organic amendments. However, the proportion of NPK fertilizers required to less dose than dry matter yield to achieve the maximum seed yield. Similarly, number of seed also followed the same trend as in seed yield. The highest diameter of inflorescences were observed in the treatment, 5.0t ha^{-1} (CD, RB, VC) and 3t PL ha^{-1} with 150% NPK in all the cases. Variation in yield attribute like weight of 100 seeds also followed to be the same trend as in yield of seed. The higher value of seed attribute was recorded in combined treatments of 7.5t ha^{-1} of CD (9.8g) and VC (7.53g) with 100 and 150% NPK respectively. However, the values recorded from plant treated with 5t ha^{-1} of RB (7.3g) and 3t ha^{-1} of PL (7.4g) with 100 and 150% NPK were very similar but requirement of organic manures less dose for RB and PL.

Content of oil and protein increased variably due to variation in treatments. The highest content of oil in seed ranged from 51.8 to 46.9% when 5.0 and 7.5t ha^{-1} of CD and VC with 150 and 100% NPK, respectively, were applied. However, the content of oil derived from seeds of plants treated with RB and PL with 150 and 100% NPK, respectively, remained in between CD and VC treated seed oil of sunflower. Protein content also followed the same pattern as in oil. The highest content of protein varied not very appreciably ranging from 33.9 (RB+100% NPK) to 30.2% (CD+150% NPK). Intermediate protein content was recorded as 31.8 and 31.0% yielded from PL 3.0t ha^{-1} and VC 5.0t ha^{-1} together with 150% NPK respectively.

Appreciable variation in B: C ratio due to variation in treatment combinations was observed. B: C ratio ranged from 3.62 to 2.51 when both CD and RB at the rate of 7.5t ha^{-1} together with 50 and 100% NPK were applied respectively. However, B: C ratio returned from VC (3.35) and PL (2.58), were observed very close, due to treatment of 5.0 and 4.5t ha^{-1} with 100 and 50% NPK respectively.

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CHAPTER 1

GENERAL INTRODUCTION

Modern agriculture, no doubt has paved the way for the "Green Revolution", but it has led to the application of heavy doses of chemical fertilizers and pesticides with the objective of maximizing the yields. Indiscriminate application of agrochemicals caused health hazards by accumulation of toxic chemical residues in animals and human beings. In the wake of serious pollution problems and bio-magnification of toxic chemicals in the various biological systems, "organic farming" is the recent approach in the present day agriculture. Organic agriculture is increasingly gaining social, political and scientific recognition for its contribution to sustainability.

Sunflower (*Helianthus annus* **L.**) is one of the most common oil crops widely grown in different parts of the world (Shoghi- Kalkhoran *et al*., 2013). World sunflower production has expended during the last decade to become the second leading oilseed crop in the world, surpassed only by soybean. The quality of sunflower oil represents about 15 per cent of the total world production of the major vegetable oils. Sunflower oil is considered as premium oil because of its light color, flavor and this oil is unsaturated with high levels of linoleic acid.

Sunflower belongs to the family compositae is native to North America and started to cultivate in Bangladesh since 1975 but on a small scale. Sunflower seed contains a high percentage of oil (40-50 %) and rich in protein 26 per cent (Khakwani *et al.*, 2014). There is high demand for sunflower because its oil is good for health as it has cholesterol free properties. One kg of sunflower seeds yields 500 to 600 grams of oil, which is significantly higher than any other oil seed (anon., 2015). The average composition of sunflower oils 55-60% linoleic and 25-30% oleic acid. This high degree of unsaturation of sunflower oil is good for edible purposes than mustard oil. Sunflower oil cake contains high in protein between 40-44% and carbohydrate 25-30% (Weiss, 1983).

Sunflower, the most important oilseed crops of the world because of the adequate concentration of unsaturated fatty acids 90% in its oil. It has gained popularity of all the oilseed crops, because of its excellent quality oil due to its richness with high degree polyunsaturated fatty acids, anti-cholesterol properties, short duration, and wide adaptability to soil and climate conditions, photo and thermo-insensitiveness, drought tolerance and higher yield per unit area (Kaushik *et al*., 2014). Its oil is practically free of significant toxic compounds and contains four important fatty acids, namely palmitic (16:0), stearic (18:0), oleic (18:1) and linoleic (18:2) acids that linoleic acid has a relatively high concentration than other fatty acids (Esmaeilian *et al.*, 2012). In a view of human health, polyunsaturated acids, such as linoleic acid (18:2), are essential to mammals and have a potent hypo-cholesterolemic effect thus lowering the risk of cardiovascular disease (Gustavo *et al.*, 2007). Dietary linolenic acid was inversely correlated with platelet function in a group of free-living subjects. The balanced between the production of thromboxane A_2, a vasoconstrictor and platelet aggregating agent, and prostacyclin, a vasodilator and inhibitor of platelet aggregation, appears to critical in the development of bleeding and thrombotic disorders (Moeskops *et al.*, 2010).

In 2017-2018 FY, world sunflower production was 46.38 million metric tons. The total production of vegetable oils worldwide amounted to185.78 million tons in 2015-2016. In 2015-2016, the global import volume of sunflower seed oil amounted to 8.97 million tons. Ukraine and Russia cover 80% of the global exports of sunflower oil (Hossain, 2014).

In Bangladesh, acute shortage of edible oil has been prevailing during the last several decades. This shortage inherited from the past has been met through imports, using a huge amount of foreign exchange every year. Bangladesh produced 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 is met through imports (Khatun *et al.*, 2016; Hussain, 2014). Bangladesh Government has to spend a huge amount of currency which value is around 1.38141 millions TK. to fulfill the demand of edible oil, every year (Khatun *et al.*, 2016). This situation could be change by increasing both the expansion of area and productivity of oil seed crops. The horizontal expansion of oil seed crops area is to difficult due to declining per capita arable land as well as competition with other crops. Day by day, the area under oil seed cultivation is declining due to various economical and technical reasons (Miah *et al.*, 2014). The present total area under sunflower and other minor oilseed cultivation is 351.82 ha with a production of 373 metric tons in 2012 (BBS, 2012). However, oil seeds cultivation area can be expand by utilizing the fallow land and the land where other crops are not fit to cultivate.

Bangladesh is vulnerable to rapidly changing climate (Miah *et al*., 2013). It is a thermo-natural crop, therefore can be grown through out Bangladesh both in rabi and kharif season. Sunflower can be cultivated in drought, limited water area, even in Barind Tract, as it requires less input such as fertilizers, chemicals and irrigation then other oil seed crops (Sheaffer *et al*., 1977). It can grow in wide ranged of soil types (from sand to clay) along with a wide range of soil P^H (5.7 to 8.5). Sunflower can tolerates approximately 2-12dsm^{-1} threshold of salinity. It is a short duration crop which can be grown in between amon and boro rice. Sunflower can be grown in the area of late rainfall or flooded area where mustard or sesame is not possible to grow. Therefore, we can boost up the production of edible oil by expending sunflower growing area. Hence, 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 (Habib *et al*., 2017). BARC has undertaken a pilot study to popularize sunflower in coastal belt and to developed local market for this crop and also has established a mill for oil extraction (Rahman, 2010). Two crops production cycles are also popular as nutrition requirement of crops is supplemented by each other cultivation like sunflower, chickpea and khesari after the cultivation of T. amon in coastal regions. It is also accepted by coastal farmer to reduce food crisis (Rashid *et al.*, 2014).

Sunflower has various kinds of importance such as domestic, industrial, animal feed, bird feed, as a source of fertilizers, soil amendment, renewable energy production and reduces green house gas emission and others but its need less inputs. Domestic demand for sunflower oil has increased in recent years as processors have built refineries and large buyers have committed to future purchases (Andaleeb *et al.*, 2008). Edible oil from this crop, about 80% of the oil is used for edible purpose and rest being non-edible. Additionally, medical uses for pulmonary affections have been reported. In addition, parts of this plant were used in making dyes for the textile industry, body painting, and other decorations. Sunflower oil is used in salad dressing, for cooking and in the manufacturing of margarine and shortening (Kunduraci *et al.*, 2010). Sunflower oil is used in industry for making paints, certain paints, varnished, plastics, manufacture of soap, production of agrochemical, surfactants, plastic, fabric softeners lubricants and coatings, detergents, pesticide carrier and cosmetics. Sunflower oil is limited use for producing bio-diesel. A coffee type could be made with the roasted seeds. In some countries, the seed cake that left after the oil extraction is used as livestock feed. In the Soviet Union, the hulls are used for manufacturing ethyl alcohol, in lining for plywood and growing yeast. The dried stems also used for fuel. The stem contains phosphorus and potassium whose can be make compost and returned to soil as fertilizer. Sunflower meal is a potential source of protein for human consumption due to its high nutritional value and lack of anti- nutritional factors (Fozia *et al.*, 2008).

Organic agriculture practices aim to enhance biodiversity, biological cycles and soil biological activity so as to achieve optimal natural systems that are socially, ecologically and economically sustainable (Akbari *et al.*, 2011). Manure is always considered as a valuable input to the soil for crop production. In a broader sense, manure management relates to the appropriate use of animal manure according to each farm's capabilities and goals while enhancing soil quality, crop nutrition and farm profits. Manure management is defined as a decision-making process aiming to combine profitable agricultural production with minimal nutrient losses from manure, for the present and in the future (Akbari *et al.*, 2011).

The organic matter content of Bangladesh soil is a low (0.82-1.2% as compared to desired (2.5% and above) level (Islam *et al*., 2010; BARC, 2012). As our land resources is limited, so the necessity of intensive cropping and cropping patterns will increase in near future because of the increasing population pressure of the country. In such a situation, it is vary alarming for future agriculture production. Now it is essential to improve the soil health and it is high time to be conscious to maximize the land degradation (Gani *et al*., 2001).

Now a days increase in the prices of chemical fertilizers, lack of consistency in feeding the soil and endangering human health cause to the increase of the use of manure for soil fertility (Esmaeilian *et al*., 2012). Manure can improve soil fertility, increase water holding capacity, decrease soil erosion, improves amount of oxygen, and promotes beneficial organisms and productivity (Esmaeilian *et al*., 2012). Organic sources such as animal manure, poultry litter, rice bran, vermicompost, farmyard manure, saw dust can be a beneficial source of major nutrient when applied at optimum rates and can influence the temporal dynamics of nutrient availability through their effects on physical and chemical properties of soil (Esmaeilian *et al*., 2012).

Application of fertilizer having nutrients like N, P and K can increase sunflower growth and yield substantially (Cechin *et al*., 2004; Sadras, 2006). NPK ratio is an important indicator in crop production that identifies balanced or unbalanced fertilization. Intensive agriculture with fertilizer use highly skewed towards nitrogen has deprived the soil of other essential nutrients especially P and K. Application of nitrogen, phosphorus and potassium fertilizer above or below the optimum level adversely affects the growth and yield. Nitrogen is the most important limiting nutrient, which helps early growth, better assimilation of carbohydrates and synthesis of proteins and as such must be supplied throughout the growth period of the crop. It also affects the seed quality by increasing protein content and decreasing oil concentration (Rasool *et al*., 2013). Sulfur is increasingly being recognized as the fourth major plant nutrient after N, P and K. It is reported that optimum fertilization with NPK increased head size, plant height, 1000 seed weight and seed yield of sunflower. Growth, seed yield, and seed oil content increased with increasing rates of nitrogen. The low soil available content is one of the main limitations to the development of sunflower considering that influences the photosynthesis, respiration, storage and energy transfer, cell-division, cell growth and several other processes in the plant. When there is no limitation of phosphorus, its uptake occurs until grain filling. The combination of phosphorus remobilized from leaves and stems to the seeds in maturation varies from approximately 30% to 60%. Application of NPK fertilizers increases sunflower growth and yield substantially (Fagundes *et al*., 2007). However, application of nitrogen, phosphorus and potassium fertilizer above or below the optimum level can adversely affect it (Nawaz *et al*., 2003; Bakht *et al*., 2010). In sunflower crop, its deficiency causes nutritional disorder, being the nitrogen that most limits the yield, providing up to 60% of reduction in productivity as a results of their disability (Chaves *et al*., 2014).

Application of chemical fertilizers has contributed significantly to the huge increase in the world for food production. The adverse impacts of excessive inputs of chemical fertilizers in conventional agricultural practices are being well documented (Garai *et al*., 2014; Mondal *et al*., 2017). Chemical fertilizers also have contributed significantly toward the pollution of soil, water and air. In agro-ecosystems, the use of synthetic toxic chemical pesticides affects the soil fertility and growth of cultivated crop (Ignacimuthu *et al*., 2007). Although excessive nitrogen fertilization can generate environmental hazard, it may also effects sunflower grains quality and decrease its oil content and reduce yield through an increase of plant lodging (Scheiner, 2002). Continuous application of synthetic fertilizer may lead to soil acidity, human health problems, and soil degradation because they release nutrients at a faster rate (Agbede *et al*. 2017). Increasing costs of synthetic fertilizers have made them generally unaffordable to most resource-poor, small scale growers. Significant reduction of sunflower yield through an increase in biomass is another effect of N fertilizer overuse (Akbari *et al*., 2011). Agricultural scientists are engaged to established agricultural systems with lower production cost and conserving the natural resources. Therefore, recent interact manure has re-emerged because of high fertilizer prices and importance of cow-dung, rice bran, vermicompost and poultry litter in maintaining long term soil productivity besides meeting timely requirement of nutrient. There is also a positive interaction between the organic manures and urea as nitrogen source (Bocchi and Tano, 1994). The addition of manures combined with chemical fertilizers could be a promising technique to increase the crop production. Therefore, adequate and balanced application of organic and inorganic fertilizers is necessary to increase productivity and soil fertility. Moreover, the addition of manures to soil may also increase the fertilizer-use efficiency, stimulate the protiferation of diverse group of soil micro-organism and play an important role in the maintenance of ecological balance of rhizosphere (Khaim *et al*., 2013).

Sunflower hybrid gave a higher yield from a combination of organic manures with chemical fertilizer (Dayal and Agarwal, 1998; Akbari *et al.*, 2011). For higher productivity and sustainability, integrated use of organic and inorganic sources of nutrients is very important (Sharma *et al*., 2014; Rasool *et al*., 2013). High yielding varieties of different crops have been cultivated several times in our country using inorganic fertilizers throughout the years. As a result, the depletion of macro and micro plant nutrients have been occurring very rapidly and potential soil health has been hampered. Thus, this research work has been initiated to find out the most effective formulation of organic manures and chemical fertilizers to maximize the yield and quality of sunflower production in the coastal districts of Bangladesh. Sunflower is highly productive in sandy loam as well as a clay loam soil. Therefore, farmers could cultivate this crop widely both in rabi and kharif seasons in the coastal areas of Bangladesh (Mahapatra *et al.*, 1989). In this context, the present experiment entitled "Integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L.)**" was undertaken at the research farm of Charfasson Govt. College, Bhola, Bangladesh during Rabi, (2015-2016) and (2016-2017) with the following objectives.

i. To assess organic and inorganic fertilizers used as a sources of nutrients for growth and yield of sunflower.
ii. To evaluate the amount of nutrients taken by the crop from organic and inorganic sources separately and combined.
iii. To measure the effects of NPK fertilizers and organic manures in various doses on grain seed protein and oil contents.

iv. To build up soil health increasing organic matter content and improving physicochemical properties of soils by the application of organic fertilizers.

v. To find out the most effective doses of (organic and inorganic) fertilizers to maximize the yield and quality of sunflower.

CHAPTER 2

2. REVIEW OF LITERATURE

The field experiments were conducted to study the integrated effects of NPK fertilizers and organic manures on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L.**) during rabi, 2015-2016 and 2016-2017 at the research farm of Charfasson Govt. College, Bhola, Bangladesh. Related literatures were reviewed and presented in this chapter.

2.1. Physiology of sunflower

Although sunflower is basically a temperate zone plant, its main commercial production takes place in the warm temperate regions (Weiss, 1983). It can grow from sea level to 2500 m, but highest oil yields are obtained from the crop grown below 1500 m. For all practical purposes, sunflower is considered to day-neutral. However, Russian workers have reported short-day, long day and insensitive types. The influence of day length lasts up to budding stage only. Under controlled conditions, development has been found to be more rapid at 12 hours day length than at 16 hours or longer (Goyne *et al.*, 1979).

Frost affects the crop to some degree at all stages of growth. It usually reduces yields by affecting the heat development. Development of seeds is also affected by frost. For commercial cultivation of the crop a frost free period of about 120 days is essential. Prolonged high temperatures reduce the maturity and adversely affect the yield and oil content of seeds. A decrease in night temperature during the period from flowering to harvest increased the linoleic acid content (Lang and Begg, 1979).

Although sunflower is considered to a drought tolerant crop any stress during the main growth period would reduce the oil yield substantially. Hair is extremely damaging to the young seedlings. If the terminal shoots are damaged the seedling would rarely recover.

The sunflower seeds show a dormancy period of 45 to 50 days. Ten days after harvest, the de-husked seeds would show only 75% germination. Ethared (25ppm) solution, equivalent to 40% of the seed volume, would effectively break the dormancy. Seeds are to be soaked for a period of 6 hours, dried under shade and sown directly. Pre-soaking treatment in sunflower is beneficial under rain-fed conditions. Pre-soaking of seeds in water, equivalent to

40% of seed volume increases the germination percentage, root, shoot length and dry weight of seedlings (Harris *et al*., 1978).

2.1.1. Botany of sunflower

~Helianthus ` originates from the Greek word `Helios' meaning sun, and `anthos' meaning flower has the same meaning as the English name sunflower, which has been given these flowers from a supposition that they follow the sun by day, always turning towards its direct rays (Lang and Begg, 1979).

Local name : Surjyamukhi

Common name: Sunflower

Botanical name: *Helianthus annus* **L**.

Family : Compositae

Order : Campanulales

2n : 34

Scientific classification

Kingdom : Plantae

Clade : Angiosperms

Clade : Eudicots

Clade : Asterids

Order : Asterales

Family : Asteraceae

Subfamily : Asteroideae

Supertribe : Helianthodae

Tribe : Heliantheae

Genus : *Helianthus* **L.**

Sunflower is a genus of plants comprising about 70 species in the family Asteraceae (Harris *et al*., 1978). Sunflower cultivation may be grouped into three types, namely Giant types, represented by Gray strips, Manchurian and Mommoth Russian; Semi-dwarf type, represented by Jupiter and Pole star; and Dwarf type having varieties such as Advent, Advance, Arrow- head, Mennonite and Sunrise. The genus is one of many in the Asteraceae that is known as sunflowers. Except for three species in South America, all *Helianthus* species are native to North America. The common name, “sunflower”, typically refers to the popular annual species *Helianthus annus*, or the common sunflower, whose round flower heads in combination with the ligules look like the sun. This and other species, notably Jerusalem artichoke (*H. tuberosus),* are cultivated in temperate regions and some tropical regions as food crops for human, cattle and poultry and as ornamental plants. The domesticated sunflower, *H. annus*, is the most familiar species. Perenial species are not as popular for gardens due to their tendency to spread rapidly and become invasive. Whorled sunflowers, *H. verticillatus*, were listed as an endangered species in 2014 when the U.S. Fish and Wildlife Service issued a final rule protecting it under the Endangered Species Act. The primary threats are industrial forestry and fine plantations in Alabama, Georgia and Tennessee. They grow to 1.8m (6 ft) and are primarily found in woodlands adjacent to creeks and moist, prairie-like areas (Weiss, 1983).

Sunflower is a tall, erect, un-branched annul. The root system is often shallow. In the unrestricted conditions, the top root may grow deep, approximately at the same rate as the stem for the first one and a half months and then more slowly. However, majority of the root growth is confined to the top layers. The stem is generally green or greenish-yellow. Sometimes it might have a bluish tinge. The stem is large, circular, bearing rough hairs with slight longitudinal ridges (Goyne *et al*., 1979). Leaves are alternately large, ovate, cordate, and carried on long petioles, estipulate. Their color is usually dark green. Leaves are highly heliotropic prior to anthesis, but this diminishes with plant maturity.

Sunflowers are usually tall annual or perennial plants that are some species can grow a height of 300 cm or more. They bear one or more wide, terminal capitula (flower heads), with bright yellow ray florets at the out side and yellow or maroon (also known as a brown/ red) disc florets inside. Several ornamental cultivars of *H. annus* have red colored ray florets; all of them stem from a single original mutant. During growth, sunflowers tilt during the day to face the sun, but stop once they begin blooming. This tracking of the sun in young sunflower heads is called heliotropism. By the time they are mature, sunflower generally face east. The rough and hairy stem is branched in the upper part in wild plants, but is usually un-branched in domesticated cultivars. The petiolate leaves are dented and often sticky. The lower leaves are opposite, ovate, or often heart shaped. *Helianthus* species are used as food plants by the larvae of many lepidopterans. The seed of *H. annus* are used as human food (Lang and Begg, 1979).

2.1.2. Origin and distribution of sunflower in the world

Sunflower was a common crop among America Indian tribes throughout North America. Evidence suggests that the plant was cultivated by natives in present-day Arizona and New Mexico about 3000 B.C. Some archaeologists suggest that sunflower may have been domesticated before corn. Although the scientific consensus had long been that sunflower was domesticated once in eastern North America, the discovery of pre-Columbian sunflower remains at archaeological sites in Mexico led to the proposal of a second domestication center in southern Mexico (Vranceanu, 1974). However, evidences from multiple evolutionary important loci and from neutral markets support a single domestication event for extant cultivated sunflower in eastern North America. They cultivated the sunflower for its seeds, which they founded into meal for cakes, mush, and bread. Spanish explorers first encountered these strikingly beautiful plants early in the sixteenth century. On their forays northward into what was to become the American Southwest. By 1550, sunflower had been brought back to Spain and Mediterranean Europe for use as an ornamental flower, and the culture then spread eastward to Egypt, India and Russia. In 1916, the English planted a process for squeezing oil from sunflower seeds. The Russians, however, deserve credit for turning sunflowers into food crop. In Europe, it becomes a very popular ornamental plant there and established as an oil seed crop. Some high yielding Russian cultivar *viz.* Peredovic, Mennonite, and Sunrise were introduced to Europe and America after the Second World War. After the discovery of Cytoplasmic male sterility by Leclereq (1969) in France, and fertility restoration gene by Kimman (1970) was introduced in the USA, hybrid sunflower types for high oil content have been produced which are now rapidly replacing the older varieties (Vranceanu, 1974).

Sunflower is now widely produced in Romania, Turkey, Bulgaria, Argentina, Spain, Yugoslavia, USA, South Africa, USSR and India. In Bangladesh sunflower as an oil seed crop has been recently introduced (1975) by the Bangladesh Agriculture Research Institute and Mennonite Central Committee (MCC). Now it produced in Patuakhali, Barguna, Jhalokhati, Perosepur, Noakhali and the various experimental fields. It is, however, a popular ornamental plant in Bangladesh. Good scope for sunflower as an oil crop exists for some areas.

2.2 Cow dung as a source of fertilizer

Cow dung, poultry litter, rice bran are most available and have huge produce and accumulation in Bangladesh (Krishna and Ram, 1996). Cow dung could be defined as the undigested residue of consumed food material being excreted by herbivorous bovine animal species. Cow dung host a wide variety of microorganisms varying in individual properties.

Manure has always been considered as a valuable input to the soil for crop production. In a broad sense, manure management relates to the appropriate use of animal manure, accordingly to each farm's capabilities and goals while enhancing soil quality, crop nutrition, and farm profits. Manure management is defined as a decision-making process aiming to combine profitable agricultural production with minimal nutrient losses from manure, for the present and in the future (Akbari *et al*., 2011)

Literature of earlier workers has been reviewed on the utilization of cow dung in the production of sunflower and its effect on soil properties was given below:

2.2.1 Effect of cow dung on physical properties of soil

Agricultural scientists are engaged to establish agricultural systems with lower production cost and conserving the natural resources. Therefore, recent interest in the manure has re-emerged because of high fertilizer prices and importance of cow dung compost in maintaining long-term soil productivity besides meeting timely requirement of nutrient. Few studies have been conducted on the use of cow dung or agricultural manure for the degradation (can say biodegradation) of contaminated soils.

Filho *et al*. (2013) reported that currently, there are several sources of fertilizers used in agriculture, but cattle manure has the greatest potential for fertilization, especially in small farms of Paraiba hinterland. However, there is not much information about the quantities to be used in sunflower crop in order to obtain a compensatory income.

Application of cow dung has been found to improve the physical properties of the soil especially the structure, porosity, water holding capacity, infiltration rate , moisture content and soil color and to reduce bulk density.

There are several sources of organic fertilizers used in agriculture, but cattle manure has the greatest potential for fertilization, especially in small farms of Paraiba hinterland. However, there is not much information about the quantities to be used in sunflower crop in order to obtain a compensatory income (Chagas *et al.*, 2013).

2.2.2 Effect of cow dung on chemical properties of soil

Hue (1992) it is well established that crop production on acid soils can be improved greatly when soil P^H is adjusted to near neutrality. Soil P^H affects nutrient solubility, and influences the sorption or precipitation of nutrients with Al and Fe. Cow dung adds organic matter into the soil, helps to increase the soils buffering capacity and regulating soil P^H (decrease soil P^H). Degraded soil may be Alkali, Acidic and Saline in nature. Application of cow dung increases the organic matter in the soil which regulates the soil reaction (P^H). In acidic soil its application increase the P^H where as in alkali soils it decreases the P^H, and thus creates favorable conditions for availability of maximum nutrients to plants (P^H range 6.5-7.8).

Chang *et al.* (1998) reported that the potential for contamination of ground and surface water through improper handling and disposal of animal manure from cattle feedlots is considerable because most feedlots have a relatively small land base and transportation costs are high. Sneh *et al.* (2006) reported that amount of soil organic matter and mineralizable C and N increased with the application of FYM, Cow dung slurry and pig slurry when applied along with inorganic fertilizers.

From the above review, it can be concluded that, continuous application of organic manures profoundly influenced many chemical properties of soil such as organic carbon content, P^H, E.C and P availability.

2.2.3 Effect of cow dung on biological properties of soil

Akbari *et al.* (2011) reported that cow dung increased the soil microbes. Soil microbes play an important role in many critical ecosystem processes, including nutrient cycling and homeostasis, decomposition of organic matters as well as promoting plant health and growth as bio-fertilization. There is evidence that organic residues from green and animal manures can increase the pH of acid soils and improve soil fertility by supplying nutrients for crop production (Hue, 1992; Iyamuremye *et al.*, 1996). The effect of animal manure on soil pH may persist over several years. Chang and Janzen (1996) reported that intensive confined beef cattle production has been increasing in Alberta for 20 years and feedlots containing more than 50000 animals are now common. Since production efficiency is improved with concentrated animal production, the trend towards intensive production units is likely to continue. Kandeler *et al.* (1999) reported that long-term application of organic amendments increased the capacity of the small- sized soil fractions to protect soil microorganisms. FYM increased the microbial biomass, N-mineralization, urease, argentine deaminase and alkaline xylanase activity and they produced some enzymes to adsorb and bind onto mineral and organic particles.

Microbial biomass C and N increased significantly with the addition of pig slurry along with inorganic fertilizers (536 mg kg^{-1} soil) than un-fertilizer soil (241mg kg^{-1} soil) (Sneh *et al.,* 2006). Bulluck *et al.* (2002) reported that number of thermophilic microorganisms were also higher in soils amended with organic amendments than soils amended with synthetic fertilizers. Actinomycetes were a major constituent of the thermophilic microorganisms detected in our study. Greater propagule densities of actinomycetes in tomato field soils under organic production compared with conventional production system in California have also been reported (Drinkwater *et al.*, 1995).

From the above review, it can be concluded that, continuous application of organic manures (Cow dung) profoundly influenced many biological properties of soil such as increase soil microorganisms population and their activity.

2.2.4 Effect of cow dung on plant nutrients

In groundnut based cropping system Subrahmaniyan *et al*. (1999) observed that soil organic carbon changed significantly with the addition of organic manures after an experiment in three year periods, but not with inorganic fertilization. Terrance *et al*. (2004) reported that the organic matter in various forms and at various stages of decomposition can be used in soil for improvement of crop productivity. The soil organic carbon content and available soil nutrients *viz*., N, P_2O_5 and K_2O after harvest of soybean and wheat were significantly higher with the application of organic manure alone or in combination with fermented organics over organics alone. Cow dung is a source of organic carbon and enriched important material, and it can be easily prevent the soil degradation. Cow dung also exhibits plants growth promoter properties (Nattudurai *et al*., 2014). Manjunatha *et al.* (2009) observed that application of recommended dose of NPK along with (7.5 t ha^{-1}) recorded significantly higher available N (26.38 kg ha^{-1}), P (37.81 kg ha^{-1}) and K (428.20 kg ha^{-1}) in sunflower as compared to application of recommended dose of fertilizer (229.45, 35.29 and 415.73 kg N, P and K ha^{-1}, respectively. In composting organic material biologically converts in to humus like substance which may be stored and applied without any environmental impact (Gallardo-Lara and Nogales, 1987).

Naveen (2009) reported that significantly higher available N, P_2O_5 and K_2O (278.5, 41.2 and 252.3kg ha^{-1}, respectively) were obtained with the application of FYM at 5 tones + bio-digester liquid manure equivalent to 10 kg N ha^{-1} over recommended FYM and inorganic (261.2, 35.8 and 232.5 kg N, P_2O_5 and K_2O, respectively). The lowest N, P_2O_5 and K_2O were recorded in FYM 10 tones +bio-digester liquid manure equivalent to 30 kg N ha^{-1} (251, 31.2 and 223.5 kg ha^{-1}, respectively).

(Bedada *et al.*, 2014) reported that human population is increasing worldwide giving rise to intensive farming system and unsuitable cropland management that ultimately results in reduced soil fertility. Extensive use of chemical fertilizers is suggested for replenishment of nutritional deficiencies to increase crop yield. Many disadvantages of widespread use of chemical fertilizers include increase in soil acidity, mineral imbalance and soil degradation and even farmers now a day do not prefer chemical fertilizers.

Ill *et al.* (2002) reported that field experiments were conducted to examine the effects of organic and inorganic soil fertility amendments on soil microbial communities and soil physical and chemical properties at three organic and three conventional vegetable farms in Virginia and Maryland in 1996 and 1997. Two treatments, including either an alternative organic soil amendment (composted cotton-gin trash, composted yard waste, or cattle manure) or synthetic soil amendment (fertilizer) were applied to three replicated plots at each grower field location. Synthetic fertilizers consisted of mixtures of nitrogen as ammonium nitrate (35.5-0-0), phosphorus as triple super phosphate (0-46-0), and potassium as muriate of potash (0-0-60). Production history and time affected propagule densities of *Trichoderma* species which remained higher in soils from organic farms. In the first year, yield of corn or melon was not different in soil amended with either synthetic or organic amendments at four of six farms. In the second year, when all growers planted tomatoes, yields were higher on farms with a history of organic production, regardless of soil amendment type. Alternative fertility amendments, enhanced beneficial soil microorganisms reduced pathogen populations, increased soil organic matter, total carbon, and CEC, and lower bulk density thus improving soil quality.

2.2.5 Effect of cow dung on sunflower growth and yield

Scheiner *et al.* (2002) suggested that excessive N fertilization of sunflower not only generates that environmental risk, it may also affect the grain quality, decreasing its oil content and reduce yield through an increase of plant lodging.

Esmaeilian *et al.* (2012) a research was carried out for determining the effects of drought stress with manures and chemical fertilizer on the quality and quality features of sunflower plants during 2009 cropping season in Gonabad where is the southeast city of Khorasan Razavi Province, Iran. The experiment was laid out in randomized complete plot design with split arrangement with three replications. Three level of water stress (S_1: full irrigation, S_2: withholding irrigation at flowering stage, and S_3: withholding irrigation at seed filling stage) were randomized to the main plot units. There were eight fertilizer treatments (F_1: control, F_2: cattle manure, F_3: Sheep manure, F_4: poultry manure, F_5: chemical fertilizer F_6: 50% cattle manure + 50% chemical fertilizer, F_7: 50% sheep manure + 50% chemical fertilizer, F_8: 50% poultry manure + 50% chemical fertilizer) were applied. Sunflower plants significantly responded to fertilizer treatments. The seed yield was highest in case of application of manure alone or in combination with chemical fertilizer than in control. Protein and oil percentage were significantly higher in F_3 (sheep manure) and F_6 (50% cattle manure + 50% chemical fertilizer), respectively. Compared to control, all fertilization methods generally increased nutrient concentration of sunflower. The highest N content was observed in F_4 and F_6 treatment. Combination of poultry manure and chemical fertilizer (F_8) led to the highest P content and Sheep manure application (F_3) resulted to the highest K content than control.

Agele and Taiwo (2013) reported that two field experiments were conducted in late season of 2009 and 2010 at the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria. To evaluates the effects of methods of seedbed preparation via clearing of existing vegetation and organic amendments on some soil properties, growth and yield of sunflower (*Helianthus annus* **L.**). The treatments consisted of 2 by 3 factorial combination of bush clearing methods and organic amendments arranged in a split- plot design. Treatments were manual clearing alone (MC), Manual clearing + organic fertilizer (MC + OF) and Manual clearing + organic manure (MC + OM) there was a un-manure herbicide –based zero tillage (Herb- Sd), herbicide –base bush clearing method + Organic fertilizer (Herb- Sd + OF), and herbicide – based zero tillage + organic manure (Herb –Sd +

OM). The observation of the result found that the highest values of root and shoot biomass, seed weight per plant and total seed yield were obtained from plots amended with organic fertilizers in both experiments over control. Cow dung manures application enhanced sunflower growth in terms of plant height, leaf area, number of leaves and leaf area index over control.

Akbari *et al.* (2011) reported that a field experiment was conducted during 2007 growing season at the Field of College of Agriculture, Tarbiat Modares University, Tehran Province, Iran. The study to fined out the effect of bio-fertilizers (*Azosporillum* and *Azotobacter*), nitrogen fertilizer (N) and farmyard manure (FYM) in various rates on the grain and biological yield, seed protein content as well as seed oil content and fatty acid composition in sunflower (*Helianthus annus* **L**. *cv. Alestar*). The experimental design was a randomized complete block (RCB) design arrangement in a split plot with three replications. Five levels of organic and inorganic fertilizers including; 0.0, 25, 50, 75 and 100% farm yard manure, 0.0, 25, 50, 75 and 100% N fertilizer. Those were applied alone and combined. Two levels of bio-fertilizer as follows: no bio-fertilizer (control) and bio-fertilizer (Inoculation with *Azospirillum* and *Azotobacter*) were randomized to the sub plot units. The finding showed that both grain and biological yield produced a better result during the combination of N fertilizer and farmyard manure than using either method alone. Maximum grain and biological yields were obtained with the F_3 treatment, respectively. The maximum protein content and protein yield /ha were recorded in the treatment of 50% FYM + 50% N) over FYM alone. The highest oil content and oil yield /ha were recorded in the treatments 100% FYM manure and 50% FYM + 50% N, respectively. The highest linolenic acid and oleic acid were observed in F_3 and F_1 treatment, respectively.

Shoghi-Kalkhoran *et al.* (2013) cited that a two-year field experiment was conducted in a semi-arid region in Iran in 2007 and 2008. To evaluate the effects of various fertilizers such as farmyard manure (FM), urea and plant growth promoting rhizobacteria (PGPR, including the genera *Azotobacter* and *Azospirillium*) were checked on yield, fatty acids, protein, and oil contents of sunflower. The experiment was a split plot in a randomized complete block design with three replicates, with five fertilizer treatments as the main plots and two PGPR treatments as sub plots. Plant received five fertilizer treatments: F_1: (100% farmyard manure (FM), 48t ha^{-1}), F_2 (75% FM+25% chemical; urea 240kg ha^{-1}), F3 (50% FM+50% Chemical), F_4 (25% FM+75% chemical), F_5 (100% chemical). Plants were also inoculated with PGPR (I_1) while non- inoculated plants (I_0) were used as control treatments. Results demonstrated that the integrated fertilizers significantly ($P \leq 0.05\%$) increased the leaf area index, plant height, grain production, biomass, oil yield, and protein content in comparison with organic or chemical fertilizers. The maximum and the minimum oil contents were obtained by applying 100% farmyard manure (F_1) and 50% FM+50% chemical (F_3), respectively; however, opposite results were observed for protein content. Bacterial inoculation also increased the leaf area index, plant height, biomass, grain and oil yields, oil content and protein contents up to 12, 3.7, 7.8, 10, 6.5, 5.6 and 5%, respectively.

Filho *et al.* (2013) reported that a experiment was carried out in a greenhouse at Universidade Estadual da Paraiba, Brasil. The aim of the present study was to effect of cattle manure on sunflower production and water use in two types of soil. The experimental design was completely randomized in a factorial scheme (2 x 4) +2, consisting of two soil types (Fluvissol- Soil-1, Haplic Luvissol- Soil-2, and four doses of cattle manure (5, 10, 15 and 20% v/v), plus two additional witnesses, which consisted of each soil, chemically fertilizer according to the recommendation with three replicates. The irrigation was performed every other day, replacing the water absorbed by the plants. Plants were harvested at 95 days after sowing when the following parameters were evaluated: number of seeds plant^{-1}, weight of seeds plant^{-1}, weight of 1000 seeds and the outer diameter of the capitulum head^{-1}. The plant cultivated in Haplic Luvisol with highest dose of cattle manure had a better performance.

2.2.6 Effect of cow dung on the growth and yield of crops

Lukman *et al*. (2016) in a study evaluated the effect of cow dung (10t ha^{-1}) and inorganic fertilizers (NPK 20-10-10) and on the performance of rice at two locations (Sokoto and Talata Mafara) in the Sudan Savana zone of Nigeria. The results showed that complementary application of cow dung and NPK fertilizers significantly ($p<0.05$) affected the yield and performance of rice in the Sudan Savana agro-ecological zone of Nigeria compared to the control plots were no fertilizer was applied. Furthermore, (complementary application of cow dung and NPK fertilizer increased most of the important growth and yield parameters (plant height, number of leaves per plant, number of tillers per square meter, grain yield and number of panicles per plant) considered except thousand grain weight.

Naveen (2009) revealed that significantly higher N, P, and K uptakes were recorded with the treatment receiving FYM at 10 kg ha^{-1} + boidigester liquid manure (CD) equivalent to 30 kg N (84.3, 8.4 and 34.3 kg ha^{-1}, respectively over recommended FYM and inorganic fertilizers (67.4, 6.4, and 25 kg N, P_2O_5 and K_2O kg ha^{-1}), respectively. The lowest uptakes of NPK were found the lowest levels of FYM and biodigester liquid manure. Minimum N, P_2O_5 and K_2O uptake were noticed with at 5t FYM + biodigester liquid manure equivalent to 10 kg N ha^{-1} (43.8, 4.0 and 14.2 kg ha^{-1}, respectively).

Suresh (2011) reported that NPK uptake (182.5, 38.5 and 181.1 kg ha^{-1} respectively) in maize with the application of FYM at 12.5 t ha^{-1} +biodigester liquid manure (CD) equivalent to 150 kg N ha^{-1}) was on par with recommended FYM+RDF (182.0, 36.5, and 175.8 kg NPK uptake ha^{-1}, respectively). Manna and Hazra (1996) reported that application of biogas slurry increased cob yield of Maize.

Omogoye and Adewale (2015) conducted a field experiment to evaluate the comparative efficacy of cow dung manure (CD) and NPK 20-10-10 in their sole and combined forms as well as their effects on some soil properties. However, the experiment consists of six treatments-NPK (0.3 t ha^{-1}), CD (3 t ha^{-1}), NPK + CD combined in ratio 1 : 2 on weight basis (W/W) (0.5 t ha^{-1}), NPK + CD at : 4 w/w (0.75 t ha^{-1}), NPK + CD at 1 :6 w/w (1 t ha^{-1}) and the control (unfertilized) pot using chilli as the test crop.

Haque *et al.* (2015) conducted to evaluate the effect of cow dung and poultry litter on the growth and yield of okra. The two factors experiment was laid out in randomized complete block design (RCBD). The highest level of poultry litter (11 t ha^{-1}) gave the best result on plant height (61.73 cm), number of leaves (16.54), leaf length (17.14cm), leaf breadth (22.13cm), green pod yield/plot (2.62kg), pod yield/ha (7.30 t) and the lowest green pod yield pot^{-1} (2.18kg), pod yield ha^{-1} (6.18 t) were recorded from control treatment. The combined effect of various level of cow dung and poultry litter also found significant. The maximum doses of cow dung and poultry litter (9t ha^{-1} and 11 t ha^{-1}) showed the best performance on pod yield (3.24 kg $plot^{-1}$), pod yield (9t ha^{-1}) and the lowest green pod yield pot^{-1} (1.80kg), pod yield ha^{-1} (5t) were recorded from control treatment.

Naing *et al.* (2010) reported that two experiments were conducted at Khon Keen University, Thailand during the rainy season of 2007 and 2008. The aim of this study was to investigate the effect of organic and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property. Experiments were laid out in a split-plot design with four replications. Four fertilizer treatments (control, Farmyard manure (FYM) or cattle manure @ 10 t ha^{-1}, NPK @ 50-22-42 kg ha^{-1}, the combination of the FYM and NPK were randomized in the main plots and five black glutinous rice varieties (KKU- GL-BL-05-002, KKU-GL-BL-05-003, KKU- GL-BL-05-004, KKU-GL-BL-05-009 and KKU-GL-BL-05-010 were randomized in the sub plots. Soil samples before fertilizer application and after harvesting were analyzed to determine chemical and physical properties. Leaf area index (LAI) and shoot dry matter were recorded at 40 days after planting, panicle initiation and flowering stages. Number of tillers and panicles per hill and grains per panicle, thousand grain weight, number of filled and unfilled grain and grain yield were recorded at the harvest time. The results from both years indicated that using the combination of FYM and inorganic fertilizers increased shoot dry matter, LAI, tiller and panicle number per hill, grain number per panicle and grain yield. It was recorded that application of FYM together with inorganic fertilizers significantly increased soil organic matter, CEC, N, P and K. Comparing among the five varieties, KKU- GL-BL-05-002 had highest grain number per panicle and grain yield in both year.

Shahariar *et al*. (2013) reported that a field experiment was conducted during rabi season in the experimental field of BCSIR to see the effects fresh and digested cow dung (CD) and poultry litter (PL) bio-slurry on the growth and yield of cabbage (*Brassica oleracea*). The experiment was laid in a Randomized Complete Block Design (CRBD) with six different treatments including control and three replications of each treatment. Six different treatments were T_1-Soil test based inorganic fertilizer (RDF); T_2- RDF + 5t ha^{-1} CD (fresh); T_3- RDF + 5t ha^{-1} CD bio-slurry (after digestion); T_4- RDF + 5t ha^{-1} PL (fresh); T_5-RDF + 5t ha^{-1} PL bio-slurry (after digestion); T_6- Native fertility (absolute control). Cabbage variety Atlas-70 was harvested at 120 days. Plant height, circumference, marketable weights and whole plant weight were examined to perceive the effects on the growth and yield of cabbages. The experiment revealed that both digested PL and CD bio-slurry had a significant effect ($P < 0.01$) on the growth and yield components of cabbage. Increased plant growth and yield were in the order of digested PL bio-slurry > digested CD bio-slurry > fresh PL > fresh CD in combination with recommended dose of fertilizers (RDF). Among the treatments, the highest head yield of cabbage (97.6 t ha^{-1}) was obtained from RDF +5t ha^{-1} digested PL bio-slurry which was 366% higher than the control.

In a four years experiment west Bengal on Entisol soils of neutral reaction containing 380 kg N, 17 kg P and 252 kg K ha^{-1} of available nutrients; a potato-groundnut-rice cropping sequence was given recommended N, P, K rates (RDF), 50%, 75%, or 150% RDF, 75 RDF +

10 t FYM ha^{-1} applied to potatoes or groundnut or 75 RDF + crop residues. The highest yield of cv. Kurfi Badsha and potatoes cv. MW-10 were 3.6 and 3.39 t ha^{-1}, respectively when given 150% RDF yields were similar to the crops receiving 75% of the RDF and potatoes additionally given 10 t FYM ha^{-1}. Groundnut cv. JI-24 yields were significantly higher with application of 75% RDF +10 t FYM ha^{-1} than application of 100 or 150 RDF. Highest net production values per unit investment were obtained with 75% RDF +10t FYM ha^{-1} (Sanyal *et al.*, 1993).

2.2.7 Economic use of cow dung and NPK fertilizers

Application of 100 per cent RDF (62.5: 75: 62.5 kg NPK ha^{-1}, respectively + 7.5 t FYM ha^{-1} in sunflower gave higher B: C ratio (3.00) as compared to only FYM at 7.5 t ha^{-1} (2.41) (Ramulu, 2009).

The maximum net return with FYM 10 tones +bio-digester liquid manure (CD) equivalent to 30 kg N ha^{-1} (Rs.15285) was found. It had higher B: C ratio of 2.09 than with FYM 10 tones +bio-digester liquid manure equivalent to 10 kg N ha^{-1} (1.77) and FYM 10 tones + bio-digester liquid manure equivalent to 20 kg N ha^{-1} (1.78). Application of recommended dose of FYM and fertilizers resulted in a B: C ratio of 1.69 with gross returns of Rs. 23912 ha^{-1}. Lowest economic returns were obtained with FYM 5 tones +bio-digester liquid manure equivalent to 10 kg N ha^{-1} (1.30 of B: C ratio and Rs. 16665 of gross returns, respectively) (Naveen, 2009). Application of FYM at 10 t +bio-digester liquid manure (CD) equivalent to 30 kg N ha^{-1} recorded higher B: C ratio (2.09) compared to FYM at 7.5 t+ 25: 50: 25 kg NPK ha^{-1} (1.69) in groundnut (Reddy *et al.*, 2010).

From the above reviews, it is clear that the combination of cow dung and NPK fertilizers are more suitable than chemical fertilizers alone or cow dung alone for sunflower and other crops production and increase soil physical, chemical and biological properties and improved soil fertility.

2.3 Rice bran as a source of fertilizer

Rice bran may be number of names, the most common being husk, hull (powder form) and chaff. Rice bran or rice hull or husk is the outermost layer of the paddy grain that is separated from the rice grains during milling process. Rice husk from paddy (*Oryza sativa)* is one example of alternative material that has a great potential. Rice bran is an agricultural residue abundantly available in rice producing countries. It is produced during rice milling; the rice bran is already dried and accumulated at the factory. The specific weight of uncomposted rice husk is about 100 kg m^{-3}. The content of each of them depends on rice variety, soil chemistry, climatic conditions, and even the geographic location of the culture (Agus, 2002).

2.3.1 Effect of rice bran on physical properties of soil

(Badar and Qureshi, 2014; Savci, 2012) reported that agriculture plays an important role in economy of developing countries like Bangladesh. However, rapid crop production with inappropriate farming practices deteriorate organic matter in soil, which results in decreased microbial activity that eventually affect its physical, chemical and biological conditions, which leads to decline in land productivity and crops yield. To solve this problem, synthetic fertilizers were always though to be a better way to improve the soil fertility and crop productivity but unfortunately the excessive use of these creates a number of serious environmental and health risk. Badar and Qureshi (2014) also reported that to minimize these hazard, naturally occurring organic fertilizers, animal and plant manures, fall residues, and food and urban wastes are batter alternate of commercially available fertilizers. Reports proved that organic farming improves soil composition, fertility, and soil fauna which in the long run have a beneficial effect on crop production. Oyewole *et al*. (2013) reported that now a day, composting is a system of recycling the organic waste matters in extra-digestible from with improving nutrient and mineral content by using beneficial microorganisms under specified conditions of temperature and aeration that could be used compost or organic fertilizers which helps to recover the soil fertility and upgrade the crop growth. Loveland and Webb (2003) reported that the rice bran improved the soil structure, water and air content of soil. In numerous studies, it is reported that addition of organic matter to soils, decreases soil bulk density values. Candemir and Gulser (2011) determined very significant negative correlations between organic matter content and bulk density values of soils in their studies. (Aliya *et al.*, 2011; Badar and Qureshi, 2014) reported that they modified soil with rice bran was found effective yields of many crops like cowpea and rice which saved 31-70% parkia biglobosa from wilting caused by *Fusarium solani* and under diverse irrigation period can give good rice stand, improve grain yield and higher water use efficiency. Loveland and Webb (2003) reported that in numerous studies, it is reported that addition of organic matter to soils decreases soil bulk density values.

2.3.2 Effect of rice bran on chemical properties of soil

Mohammed *et al*. (1999) reported that organic fertilizers (RB) increase the CEC of soil and soil organic matter, improvement of soil chemical properties, and increase of crop yield. Rice bran compost is used as a source of organic matter is consists of partly separated and subjected to fermentation of organic waste. Especially in organic farming, the use of compost is one of the methods to increase the organic material contents of processed and unprocessed soil. Candemir and Gulser (2011) reported that soil P^H values significantly decreased with rice bran compost application. Carbon dioxide released into soil atmosphere due to decomposition of organic wastes could be convert into carbonic acid (H_2CO_3) by reacting with water (H_2O) and decreases soil P^H. Application of different agricultural wastes, especially tea waste, decreased soil P^H values in different textured soils. Research has shown that incorporation of rice husks and rice straw can significantly improve soil chemical properties such as enhancing soil P^H, adding organic carbon, increasing available nutrients and removing heavy metals from the system, ultimately increasing crop yields (Williams *et al*. 1972). Candemir and Gulser (2011) reported that E.C values of the soils significantly increased with the ricebran compost application. Many researchers reported that addition of organic matter and compost to the soils increased electrical conductivity significantly. Candemir and Gulser (2011) also reported that application of different agricultural wastes especially tea waste, decreased soil P^H values in different textured soils. E.C values of the soils significantly increased with RHC application. Similar studies on cowpea, soybean, and maize (Yamato *et al.* 2006) have also supported the application of biochar as a way to increase crop yields. Asia, a principal rice grown region, has abundant rice residues, estimated at about 560 million tones of rice straw and 112 million tones of rice husks, respectively. These residues could be a valuable resource for the production of biochar to increase soil fertility.

2.3.3 Effect of rice bran on biological properties of soil

Soil microorganisms are likely to have been critical in the biogeochemical cycles of both inorganic and organic nutrients in soil and in the maintenance of soil health and quality (Jeffries *et al.*, 2003). Beneficial free living soil bacteria isolated from the *rhizophere,* which have been shown to improve plant health or increase yield, are usually known as plant growth promoting *rhizobacteria* (PGPR) Suslow and Schroth (1982). Organic waste applications cause an increase in biological activity and biomass in soils. Ca is one of the most important components of the biomass after nitrogen, phosphorus and potassium. On the other hand, exch. Mg values of the soil significantly increased according to the control treatment with rice bran composts application and increase microbiological activity of soil (Shoghi-Kalkhoran *et al.*, 2013). Badar and Qureshi (2014) reported that composted RH in two quantities (5 and 10 g/2 kg soil pot^{-1}) was added on the 7th day of the germination of developing seedlings of sunflower plants where CRH has proved its potential in growth promotion and improvement in biochemical parameters of plants. But effects vary with the microbial treatments involved in composting like rice husk (RH) composted with *T. hamatum* (JUF1), *Bradyrhizobium sp-ll* (JUR2), and combination of *T. Hamatum* with *Rhizobium sp.* (JUR1 + JUF1). They found effective in improving the shoot and root lengths, total chlorophyll, and biochemical parameters including crude protein and mineral (nitrogen & phosphorus) contents of sunflower plants as compared to control plants treated with uncomposted in rice husk (UCRH). It clearly appeared that the addition of CHR might be enhanced the organic content of soil which not only help in growth of plants but also make them these healthier in term of biochemical parameters. Mahrous *et al.* (2014) reported that soil microbial status before cultivated, growth and harvest stage of experiment of two seasons evaluated by using organic fertilizer with 50% of mineral fertilizer and mixtures NPK –bio-fertilizers. The data presented in table indicated that the initial numbers of total bacterial counts were 25 and 35 x 10^{6} cfu g^{-1} dry soils for season 2010 and season 2011, respectively, and recorded the lower values as compared to all tested treatments of sunflower plants. Applying of mineral fertilizer led to give a significant difference at total bacterial counts as compared to initial counts and recorded percentage increase ranged from 168 to 132 % for season 2010 and 46 to 86 % for season 2011 as an average for Giza 102 and Sakha 53 sunflower plant.

2.3.4 Effect of rice bran on plant nutrients

Shoghi-Kalkhoran *et al.* (2013) reported that organic fertilizers play a major role. Organic manures contain valuable nitrogen sources, phosphate and potash that could be used in the farm for several years. Organic waste used as regulators meets especially the nutrient requirements of the plants as well as many functions of soils. With the use of compost, organic substances lost from soils in various ways are again given into soils and thereby nutrient loss reduced. Studies on cowpea, soybean and maize (Yamato *et al.*, 2006) have also supported the application of biochar as a way to increase crop yields. Beside this, it is also involved in phyto remediation and used to extract toxic ingredients such as lead, arsenic, and uranium from soil. Manure treatment increased available K and Mg contents of the soils. Williams (1972) reported that manure treatment increased available K and Mg contents of the soils. Organic acids as a decomposition product of organic matter provide plant available nutrients, particularly phosphorus and micronutrient. Rice bran enhance soil P^H, adding organic carbon, increasing available nutrients and removing heavy metals from the system, ultimately increasing crop yields.

Solomon and Ogeh (1995) indicated that leguminous materials and rice husk supplied mainly N, P, K, Zn, Fe, Cu, Mn and B to the soil those NPK 15-15-15 fertilizer did not process. Badar and Quresh (2014) reported that rice husk composted with JUF1 in amounts of 5 and 10 g enhanced the nitrogen content as 236 and 40%, respectively, in plants on 30^{th} day. Whereas RH composted with JUR2 (10 g) was found helpful in the same aspect on 60^{th} day. RH composted with JUR1 +JUF1 has accelerated the nitrogen content with 170% in plant on 30^{th} day. RH composted with JUF1 in both amounts (5 and 10 g) increased the phosphorus content in experimental plants by 400% on 30^{th} day and 89% on 60^{th} day, respectively. Similarly, RH composted with JUR2 stimulated the phosphorus content of plants by 186% on 30^{th} day.

Akter *et al*. (2017) reported that a study was conducted with a T. Boro rice cultivar (BRRI dhan64) at Musulliabad (Lata Chapli), Kalapara, Patuakhali, Bangladesh during January to June, 2016. The experiment was conducted following 3 factorial designs having 3 replications. To evaluate the impacts of indigenous organic amendments such as rice hull, rice straw and saw dust alone and in combination under variable moisture conditions on the primary nutrients (N, P and K) of BRRI dhan64 grown in a coastal saline soil. Basal doses of N, P_2O_5 and K_2O were applied at the rate of 120, 60 and 80 kg ha^{-1}. The individual application of rice hull, rice straw and saw dust at the rat of 0, 4 and 8 t ha^{-1} and their combined effects were found to be significant ($P< 0.05$) for N content in the rice plants. Effects of the treatments on P content alone and in combination were slightly additive but not significant. The maximum P content in the plant tissues was determined at saturated condition with the increased rate of the treatments ($RH_8RS_8SD_8$), while the lowest content of P was recorded in control ($RH_0RS_0SD_0$). The K content in plant tissues increased significantly ($P < 0.05$) with the increased rate of application of rice hull, rice straw and saw dust. This experimental scientist suggested that the primary nutrition of rice had better response under saturated moisture condition in saline soil, which received rice hull, rice straw and saw dust.

2.3.5 Effect of rice bran on sunflower growth and yield

Mahrous *et al.* (2014) two field experiments were carried out in 2010 and 2011 summer seasons to study the effect of mineral, organic, natural rocks and bio-fertilizers on the yield and yield components of Sahka 53 and Giza 102 sunflower varieties in newly reclaimed soils. The field experiments were layout at the Agricultural Experimental Desert station, Faculty of Agriculture, Cairo University at Wadi El-Natroon, El-Beheira Governorate, Egypt. The experiments included 16 treatments which were the combinations of: 1. Two seed oil sunflower varieties, Sakha 53 and Giza 102. 2. RDF N: P: K: (12:11:18), Compost, natural mineral rocks (15% P_2O_5), (10% K_2O) and (15% MgO), PGPR three types, N, P and K fixing bacteria, and 8 organic and inorganic fertilizer treatments, alone and combined. The results showed that the applying of organic fertilizers, natural mineral rocks and bio-fertilizers had positive effect on yield and yield components of two sunflower varieties under sandy soil condition as compared to NPK mineral fertilizers. Fertilizer with various rates of compost, natural mineral rocks and biofertilizers increased head diameter, seed yield/plant, seed yield /faddan and 100-seed weight by 4%, 5%, 13% and 5% as compared to plants received recommended NPK mineral fertilizer dose, respectively at the first season. The corresponding values at the second one were 4%, 8% 19% and 3% in the same order. The obtained results showed that, there were no significant effect of the interaction between the varieties and various form of fertilization (organic, bio and mineral) application in most of the studied traits except in seed oil content and seed protein content in both seasons.

Bader and Qureshi (2014) reported that a pot experiment carried out of the Department of Botany, Jinnah University for women, Karachi, Pakistan to investigated the effects of composted rice husk (5 and 10 g/ 2 kg of soil/pot) on growth and biological parameters of sunflower plants at the 30^{th} and 60^{th} day of germination. Result showed significantly ($P < 0.05$) improvement in growth and biochemical parameters of plants as compared to control plants treated with undecomposted organic fertilizer. However, the effects vary with the microbial treatments involved in the composting of rice husk like composted with *T. hamatum* (JUF1), *bradyrhizobium sp*-II (JUR2) alone, and JUF1 in combination with *Rhizobium sp*-I (JUR1) were found effective in improving the shoot and root lengths, total chlorophyll, carbohydrate, crude protein, and mineral (nitrogen and phosphorus) content of sunflower plants. It indicates that composted rice husk with improved total carbohydrate and protein contents may increase the soil fertility by improving its organic content.

Rasool *et al.* (2013) reported that a field experiment was conducted at the Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Science and Technology, India for two consecutive rainy (kharif) seasons of 2009 and 2010 to find out the impact of nitrogen, sulfur and cattle manure on growth and yield of sunflower (*Helianthus annus* **L**.). The experiment was laid out in factorial randomized block design with three replications. The treatments comprised of three nitrogen levels *viz.* 40, 80 and 120kg ha^{-1}, two sulfur levels *viz.* 30 and 60 kg ha^{-1} and three levels FYM treatments *viz.*, 0, 10 and 20 t ha^{-1}. P @ 60 kg ha^{-1} and K @ 40 kg ha^{-1} were uniformly applied to each plot as a basal dose. Application of 120 kg N ha^{-1} significantly increased all the yield components *viz*. plant height, leaf area index, dry matter production, capitulam diameter, achenes $capitulum^{-1}$ and 1000-seed weight. With increased N dose, the oil content consistently decreased but the oil yield improved during both years. Application of S @ 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 ha^{-1} were significantly higher than those of 30 kg S ha^{-1}. Similarly, oil content and oil yield with 60 kg S ha^{-1} was 2 and 10.5% over 30 kg S ha^{-1}. Application of FYM @ 10 and 20 t ha^{-1} was at par with each other but recorded significantly ($P< 0.05$) 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.

2.3.6 Effect of rice bran on the growth and yield of crops

Moghadam and Heidarzadeh (2014) evaluated the effect of silicate fertilizer, rice husk, and rice husk ash at different levels in treatments on rice growth and yield. Measuring of plant attributes were recorded in three stages maximum tillaring, flowering and maturity.

The results showed that by applying related treatments morphological specifications, plant height, number of tiller, leaf area, leaf stem and total dry weight and silicon density in leaf texture and stem and progressive processes which in tillaring stage was significant 1% level. Also by applying treatments at different levels showed the increase in grain yield that was significant at 5% level. It suggested that rice husk could be used as it is a source of silicon.

Sistani *et al.* (2008) conducted a greenhouse experiment to study the effect of Si from rice hull ash (RHA) on the growth of rice (*Oriza sativa* **L.**) seedlings. Rice hull ash was applied to in two Malawian rice cultivar grown on three soil types at the rate of 0.0, 0.5, 1.0, and 2kg m^2. The RHA- treated seedlings produced (average of all treated seedlings more dry matter (18%) over the untreated seedlings. The treated seedlings also reduced the uptake of N (16.4%) by shoots than the untreated seedlings. The effects of rice cultivar and soils on the seedling growth were not significant. The RHA application to rice nurseries seems to be an efficient way of recycling plant Si and have agronomic and environmental benefits, especially in developing countries.

Awodun (2007) reported that rice bran applied to soil significantly increased soil and leaf N, P, K, Ca, and Mg contents and number of leaves and grain yield of cowpea.

Yankaraddi *et al.* (2009) conducted a field experiment during kharif to study the effect of organic sources on growth, yield and nutrient uptake of rice at the Zonal Agricultural Research Station, Mudigere. Treatments consisted of organic sources *viz*., coffee pulp compost, rice hull ash and FYM combined with 50 or 100 per cent recommended fertilizers. The results revealed that application of FYM @ 10 t ha^{-1} + rice hull ash @ 2 t ha^{-1} +100% RDF recorded highest grain (6.24 t ha^{-1}), straw yield (7.49 t ha^{-1}), nutrient content (2.51% N, 0.61% P and 2.91% K) and nutrient uptake (170.66 N, 41.14 P and 209.76 K kg ha^{-1}). It was followed by application of coffee pulp compost @ 2.5 t ha^{-1} + rice hull ash @ 2 t ha^{-1} +100% RDF. After harvest of the crop, available nitrogen, phosphorus and potassium in soil maximum in the above mentioned treatments.

Kamara *et al.* (2015) conducted a pot experiment to investigate the effects of application of biochar from rice residues on (i) soil physiochemical properties and (ii) the early growth characteristics of two rice varieties, NERICA L19 and ROK3. Results showed that application of biochar improved available phosphorus, exchangeable cations and cation exchange capacity in biochar treated soils compared to the control soil without biochar. Plant height, tiller number, and dry biomass weight of both rice varieties grown in soils amended with rice straw biochar were significantly higher than those on untreated soil. The most remarkable increase in plant growth characteristics as a result of biochar addition to soil was reflected in the biomass yield and tiller numbers. Dry shoot biomass for Rok3 rice variety varied significantly from a mean of 3.5 g (control) to 26.2g + (biochar). Similarly, for NERICA L19 rice variety, dry shoot biomass increased significantly from 4.5 g (control) to 22.7 g + (biochar) while tiller numbers increased significantly from a mean of 12.3 (control) to 30 + (biochar).

Pratiwi and Shinogi (2016) investigated the effects of the application of rice husk boichar on selected soil physical properties, rice growth, including root extension, and methane (CH_4) emissions from paddy field soil. The experiments showed that the application of rice husk biochar improved the physical properties of paddy soils. The results showed a decrease in bulk density and an increase in saturated hydraulic conductivity, including the total pore volume as well as the available soil water content. The shoot higher of rice plants was significantly higher in soil amended with 4% biochar than that in the control soil.

Semiha (2009) investigated the effects of rice husks on yield and quality of potato (*Sante cv*.). In the study, treatments including control (no fertilizer), farmyard manure (10 t ha^{-1}) rice husk (1 t ha^{-1}) and farmyard manure + rice husk (10 + 1 t ha^{-1}) were used. Total tuber yield was significantly affected by treatments. In rice husk treatment, tuber yield, tuber number per plant and mean tuber weight were as high as in farmyard manure and farmyard manure + rice husks. Three were no significant differences among treatment in dry matter content and bulk density of tuber. Whereas protein and ash content of tuber were significantly affected by treatments. This study showed that total and first class yield of potato increased with application of rice husk.

Abrishamkesh *et al.* (2015) in their study evaluated the effects of rice husk biochar application on some properties of an alkaline soil and on lentil (Lens culinaris Medik) growth. Lentils were grown in the soil amended with the rate of 0.4, 0.8, 1.6, 2.4, and 3.3 weight per cent of two biochars, produced from rice husk under different pyrolysis conditions. Soil sample were also analyzed for changes in physico- chemical properties. The results indicated that biochar application significantly increased soil organic carbon, cation exchange capacity, available potassium and below ground biomass of lentil, while it decreased soil bulk density. The results suggested that biochar application to alkaline soils has benefits to both soil quality and plant growth.

Sarah *et al.* (2013) evaluated the effect of rice husk char (potentially biochar) application on the growth of transplanted lettuce (*Lactuca sativa)* and Chinese cabbage (*Brassica chinensis*) in a pot experiment over a three crop (*lettuce- cabbage-lettuce)* cycle in Cambodia. The biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments. The highest biomass increase due to biochar additions was found in the soils without fertilization, rather than fertilized soils with the same biochar application.

Uguru *et al.* (2015) reported that application of rice husk dust significantly increased the total porosity, hydraulic conductivity and maize grain yield. Un-burnt plus burnt rice husk dust recorded the highest improvement in soil physical properties and maize grain yield. Un-burnt rice husk dust improved the selected physical properties higher than burnt rice husk dust and the improvement increased with an increase in quality of rice husk dust applied. While application of un-burnt plus burnt rice husk gave the highest maize grain yield.

Moyin- Jesu (2015) reported that the highest values of cabbage head yield parameters obtained with poultry manure followed by wood ash and rice bran, respectively. When compared to NPK 15-15-15, application of poultry manure also increased cabbage head weight, head girth and head length by 17, 18, and 8% respectively. The application of poultry manure also increased cabbage head weight, head girth and head length by 23, 21 and 13% compared to the wood ash treatment, respectively. The least values of cabbage yield parameters obtained under the control treatment.

Lee (2010) reported that a field experiment was conducted at the experimental farm of the onion Research Institute, Changnyeong district, Korea. The experimental site had been under continuous cultivation by a double cropping system of rice followed by bulb onion (*Allium cepa* **L.**) and managed organically without the use of any chemicals for 3 years before starting this experiment. Now, this study was carried out to maximize the fertilization efficiency of mixed organic fertilizer (OF) for organically managed onion (*Allium cepa* L.) production during the one growing season of 2005-2006. The organic fertilizer was made of organic materials like sesame oil cake, rice bran and molasses and minerals like illite and mountainous soil. Four organic topdressing treatments, which all followed the same basal fertilization with solid OF, consisted of solid OF without mulch (OF/OFuM), liquid organic fertilizer without mulch (OF/LOFuM), liquid organic fertilizer under mulch (OF/LOFuM) and liquid fertilizer without mulch (OF/LOFoM). Chemical fertilizer (CF) and no fertilizer

(NF) were treated as controls. The solid organic fertilization base was 2.0t ha^{-1} and 4.57 tons ha^{-1} and was used for topdressing. The total amount of liquid organic fertilization was 133.2 tons ha^{-1}, which was divided into 6 applications from February through March. The OF/LOFuM and OF/LOFoM topdressings did not reduce onion height, leaf number or bulb diameter as compared to chemical fertilizer, whereas no mulch treatments made onion growth significantly ($P<0.05$) poorer. Onion top weight in CF was significantly ($P<0.05$) higher than that in OF groups at the peak growth stage, while there was not mulch difference in bulb weight between the CF and OF/LOFoM treatment. Finally, the onion marketable yield was 45.9 ton ha^{-1} in the OF/LOFoM treatment, which exceeded that in the CF treatment by up to 1.9 tons. Furthermore, OF/LOFoM was the most effective among all the treatments in transferring the nutrients from sink to source.

2.3.7 Economic use of rice bran and NPK fertilizers

Khatik and Dikshit (2001) estimated the economics of sunflower cultivation during Rabi season at Madhya Pradesh, using recommended dose of fertilizer (RDF) and different organic manures (FYM and compost). The recommended fertilizer rate of 12 kg N, 80 kg P and 40 kg K ha^{-1} were used. The study revealed that the highest net return (Rs.7461. ha^{-1}) and C: B ratio (1:2.17) resulted in treatment of NPK fertilizers + compost at 10 tones ha^{-1}.

Basavaraju and Purushotham (2009) reported that 50 per cent N through FYM +50 per cent NPK through fertilizer in finger millet recorded higher B: C ratio (2.03) as compared to recommended N with available P and K through vermicompost (1.08).

From the above literatures, it is clear that the combination of rice bran compost and NPK fertilizers are more suitable than chemical fertilizers alone or rice bran alone for sunflower and other crops production and increase soil physical, chemical and biological properties and improved soil health by increasing plant nutrients and reduce environmental hazards.

2.4 Poultry litter as a source of fertilizer

Poultry litter is a mixture of manure and bedding materials those are produced in large amount annually in the country. Poultry litter, if properly handled, is a valuable organic source of essential plant nutrients and soil amendment to improve soil quality (Mullins, 2002). Applying poultry litter to agricultural lands is a proven, environmentally sound method for recycling essential nutrients as well as crop production.

Literature of earlier workers has been reviewed on the utilization of poultry litter in the production of sunflower and its effect on soil properties was given bellow:

2.4.1 Effect of poultry litter on physical properties of soil

Integrated nutrient management is a recent approach stabilizing production of crops (Patil and Deshpande, 1999). (Alabadan *et al.*, 2009; Muhammad *et al.*, 2007) conducted an experiment with the waste of cockerel, layer and broiler in sandy clay loam soil to investigate soil properties. The results revealed that, application of broiler manure comparatively better performance to increase soil physical properties.

Agbede and Adekiya (2011) application of poultry manure, + NPK fertilizers significantly reduced soil bulk density, temperature and increased soil water content and porosity, where as application NPK fertilizer alone did not improve soil physical properties. Adebayo *et al*. (2010) research have shown that compost and other organic manures can serve as soil amendments to improve soil nutrient and water holding capacity particularly in sandy soil. (Prasanthrajan and Kannan, 2007) reported that poultry manure has been used as a management tool to stabilize large quantities of livestock and poultry manure that might otherwise generate NH_3, odors and propagates files. It was reported that application of compost increased the dry matter production, yield and other physiological attributes of groundnut crop and cowpea. A sustainable agricultural system must be economical sound, socially acceptable and environmentally compatible. The challenge of sustainable agricultural research and education programme is to develop systems that meet these three inter connected goals. A sustainable approach requires producers to substitute management, scientific information and or farm resources for the purchase inputs on which their farming enterprises currently depend. Some of those purchased inputs are pesticides and fertilizers. Over the year, a number of research projects have focused on the ability of compost to reduce the need for those imputs.

Prasanthrajan *et al.* (2014) reported that poultry manure was found best to reduce soil physical parameters such as bulk density (0-30 cm depth), mean weight diameter (0-30cm), and basic infiltration rate to the extent of 11.3-31.3%, 6.7-18.0%, 37.20-76.5%, respectively.

2.4.2 Effect of poultry litter on chemical properties of soil

(Adediran *et al.*, 2003) poultry manure stabilize soil P^H, increase soil buffering capacity, CEC, surface behavior of silicate clay, soil organic matter and ultimately improve plant growth and yields. Compost may be utilized as an alternative to polyethylene mulches and serve as an alternative form of weed control and increase soil fertility in crop production systems. The advantage of ready availability of materials for their preparation, gradual release of plant nutrients without being wasted through leaching or erosion, destruction of harmful weeds and toxic materials during preparation and being environmentally friendly has made composted manure popular among farmers. The aforementioned advantages of compost application in crop production have long been recognized. However, to obtain maximum benefit certain conditions must be considered and this includes: suitably balanced ratio of nutrients possible presence of toxic materials unaffected by biological degradation in the soil, possible presence of harmful microorganisms and suitable degree of stabilization of organic material. Effectiveness of compost depends primarily on source and type of organic material method of composting and compost maturity. Mature compost provides a stabilized form of organic matter and has the potential to enhance nutrient release in the soil more than do raw organic wastes.

Codling *et al.* (2008) was performed a research to asses the long term effect of poultry litter applications on soil P, Cu. Zn, Mn, and As concentration in Chesapeake Bay water sad coastal plain soils. Litter and soil samples were collected ten farms with more than 40 years of broiler production and from wooded sites adjacent to fields and analyzed for P and metal contents. Averaged over farms, total P and metal concentration in the litter were 12.80 gm kg^{-1} P and 332, 350, 334 and 2.93 mg kg^{-1} Cu, Zn, Mn and as respectively. Surface (0-15 cm) soil P^H values were greater (5.7-6.4) than the 0 to 15 cm wooded sites (3.5-4.3). Surface soil Bray 1 P values (149-796 mg kg^{-1}) in amended fields were greater than wooded sites (4.4-17 mg kg^{-1}). The 1 N nitric acid extractable metal concentrations were higher in amended soils than in wooded areas and were 7.7-32, 5.7-26, 12.3-71 and 0.6-3.0 mg kg ha^{-1} for Cu, Zn, Mn and As, respectively, compared to 0.76-14, 4.6-22, 1.6-70 and 0.14-0.59 mg kg^{-1} for the same metals respectively, in wooded areas. Results from this study demonstrated that long term broiler litter applications have altered the chemical properties of the Coastal Plain Soils of the Maryland Eastern Shore. Metal concentrations were low in the surface layer of amended fields and typically decreased with depth. Phosphorus additions rather than metals are most likely to contribute to the degradation of the Chesapeak Bay water shed.

2.4.3 Effect of poultry litter on biological properties of soil

Poultry manure increases soil microbial activity and its production. Soil microbes play an important role in many critical ecosystem processes, including nutrient cycling and homeostasis, decomposition of organic matter, as well as promoting plant health and growth as bio-fertilization (Akbari *et al*., 2011). Crushed cotton gin compost (CCGC) and poultry litter were applied to observe the effect of soil biological properties. After completion of study soil microbial biomass and soil enzyme activities were generally higher in the poultry litter amended soil compared to the CCGC amended soil. Sunflower hybrid gave a higher yield from a combination of organic manures with chemical fertilizer (Dayal and Agarwal, 1998; Akbari *et al*., 2011). Tajeda *et al*. (2006) cited that poultry litter contributes to soil biological properties (soil microbial biomass). They applied the sources of organic waste *viz*., a crushed cotton gin compost (CCGC) and poultry litter (PL) to observe the effect of soil biological properties. After completion of study of soil microbial biomass and soil enzyme activities were generally higher in the PL amended soil compared to the CCGC amended soil. Abdel Hamid *et al.* (2004) found from an experiment that composting of rice straw with poultry manure enhanced soil chemical and biological properties. A pot experiment was carried out in Gifu University, Japan, in 2001-2002. The composts of rice straw and poultry manure reached maturity in 90 days, were reaching in organic matter and mineral nutrients, and had a high level of stability and no phyto-toxicity. The addition of rice straw and poultry manure compost (20-200 g pot^{-1}) improved selected soil chemical (increased total N, total C and CEC) and biological (increased soil respiration rate) properties.

2.4.4 Effect of poultry litter on plant nutrients

Poultry manure is an effective source of nutrients for crops (Habimana *et al*., 2014; Agbede *et al.*, 2017). Poultry litter contains all 13 of the essential plant nutrients that are used to by plants, these includes nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu) zinc (Zn), chlorine (Cl), boron (B), iron (Fe) and molybdenum (Mo). Moyin-Juse (2019) reported that a field experiment was carried out in Akure in the rain forest zone of Nigeria to determine the effect of poultry manure, wood ash and rice bran on the soil fertility improvement, growth and head yield of cabbage (*Brassica oleraceae* **L**.) in 2011 and 2012 cropping season. There were three organic fertilizers treatments, namely poultry manure, wood ash and rice bran, applied at 6 t ha^{-1} with a reference treatment NPK $_{15\text{-}15\text{-}15}$ fertilizer applied at 300 kg ha^{-1} and control treatment (no fertilizer). The experiment was arranged in a randomized complete block design with replicated three times. The highest values of soil O.M. and moderate values of soil P, K, Ca and Mg were obtained with application of poultry manure compost to NPK fertilizer. However, the highest K/Ca, K/Mg and P/Mg ratios 93: 1, 74: 1 and 57: 2.1, respectively, were obtained under $NPK_{15\text{-}15\text{-}15}$ fertilizer application compared to 2: 1 K/Ca, 2: 1 K/Mg and 16: 1 in rice bran treatment.

McElvany *et al.* (2004) reported that a study area in coastal plain (Quitman country) of Georgia to determine the benefits of application of diammonium phosphate (DAP) and poultry litter to planted loblolly pine (*Pinus taeda* **L**.) seedlings on an old field site. Treatments were control (no manure and fertilizer), Spot surface application of DAP, poultry litter sole, banded herbicide only, DAP + herbicide, poultry litter + herbicide. Loblolly pine ground line diameter (GLD), total height and soil pH, P, K, Ca, Mg, Cu, Zn were not significantly affect with the application of DAP and poultry litter alone but, combined application of DAP and poultry litter represented the adjuvant results.

2.4.5 Effect of poultry litter on sunflower growth and yield

Application of FYM at 7.5 t ha^{-1} + recommended dose of fertilizer (RDF), significantly increased the 1000 seed weight (49.26 g), head diameter (17.71 cm), seed weight head^{-1} (31.91 g), seed yield (1774 kg ha^{-1}) and stalk yield of sunflower (4.21 t ha^{-1}) than RDF (45.56 g, 16.41cm, 28.97 g, 1611 kg ha^{-1}, 3.29 t ha^{-1}, respectively) but it was on par with application of FYM at 7.5 t ha^{-1} + jeevamrut (Manjunatha *et al.*, 2009).

Esmaeilian *et al.* (2011) reported that a field experiment was conducted in an experimental farm in the city of Gonabad, Iran, during growing season of 2010, to study the response of sunflower to combination of different sources of organic manure with inorganic fertilizer under drought stress at reproductive stage. The trail was laid out using a randomized complete block design with split-plot arrangement with three replications. Main plot composed of three levels included: control (normal irrigation), irrigation missing at flowering stage and irrigation missing at seed filling stage. Sub plot composed of eight levels included: F_1: control, F_2: cattle manure, F_3: Sheep manure, F_4: poultry manure, F_5: chemical fertilizer, F_6: 50% cattle manure+50% chemical fertilizer, F_7: 50% sheep manure+50% chemical fertilizer, and F_8: 50% poultry manure+ 50% chemical fertilizer. The results of present study clearly indicated that among fertilizer treatments, sunflower plants treated with F_2, F_4 and F_6 treatments showed the highest and control had the lowest amounts in all quantitative traits measured in this experiment. F_3 and F_4 treatments as a source of organic manures were statistically superior to other treatments in protein percentage and protein yield, respectively. On the other hand, maximum seed oil content and oil yield were recorded, when crop fertilizer by cattle manure alone.

Buriro *et al.* (2015) reported that a field experiment was conducted during 2012 at Students' Experimental farm, Department of Agronomy, Faculty of Crop production, Sindh Agriculture University Tandojam to investigate the response of sunflower to conjunctive use of organic manures and inorganic NPK fertilizers. The experiment was laid out in three replicated randomized complete block design. They arranged the treatments in this way: Recommended NPK (120+60+60) considered as control, 50 and 75% RDF, Poultry manure (PM) @ 6 and 8 t ha^{-1}, Buffalo manure (BF) @ 6 and 8 t ha^{-1}, Goat/sheep manure (BF) @ 6 and 8 t ha^{-1}, PM+BM+GSM each @ 2 t ha^{-1}. The results revealed that all the growth, seed yield characters and oil content were significantly ($P< 0.05$) affected by conjunctive use of different organic manures and inorganic NPK fertilizers. For the sunflower seed yield and most of its components, RDF 100% NPK ranked 1st resulting in 201 cm plant height, 3.71 cm stem girth, 20.70 leaves $plant^{-1}$, 19.49 cm head diameter,1650.91 seeds $head^{-1}$, 66.04 g seed weight $head^{-1}$, 60.62 g seed index, 2017.7 kg ha^{-1} seed yield and 44.34% oil content. The crop under treatment PM @ 8 t ha^{-1} + 50% RDF NPK ranked 2^{nd} in all the growth, seed yield characters and oil content. It was concluded that poultry manure and goat/sheep manure @ 6t ha^{-1} or @ 8 t ha^{-1} replacing 50% recommended dose of NPK fertilizers, respectively showed more promising results as compared to buffalo manure, while combined application of poultry, goat/sheep and buffalo manure could not surpass the effectiveness of poultry and goat/sheep manure.

Prasanthrajan *et al.* (2014) reported that a field trail was conducted at farmer's field, Narasipuram village, Coimbatere, Tamil Nadu, India. To test the effectiveness of poultry–carbonaceous wastes compost on the soil properties, growth and yield attributes of sunflower (Var. COI). The experiment was laid out in a Randomized Block Design with three replications. There were 12 treatments. Absolute control, 100% NPK: @ 60: 45: 45kg ha^{-1}. 75% NPK, FYM @ 12.5t ha^{-1}, Compost mix (Poultry droppings, Coir pith and Paddy straw) @ 6 t ha^{-1} and Rock phosphate, and their combined doses. Application of compost improved the soil fertility by adding humus and nutrients. Compost along with 100% NPK (60:45:45kg NPK ha^{-1}) and 75% (45:33:33kg NPK ha^{-1}) recommended NPK increased the growth and yield of sunflower. The coir pith and rock phosphate added poultry compost along with recommended levels of NPK recorded higher yield. Compost application improved the crop yield, soil fertility status and saved 25% of inorganic fertilizer.

Kulkarni *et al.* (2002) reported that a field experiment conducted at Raichur, Karnatoka, India, during rabi season 1999-2000 using factorial randomized design with three replications to study the influenced of organic manures, bio-fertilizers and micronutrients on growth, yield and yield parameters of sunflower. Micronutrients spray FeSO4 (1.0%), MgSO4 (1.0%) and Boron (0.2%). The result indicated that the highest grain yield among the organic manures was recorded by application of Poultry manure (1877 kg/ha) as compared to the application of FYM (1659kg/ha) and no organic manure (1413kg/ha). Application of Poultry manure significantly increased the number of leaves $plant^{-1}$, dry matter production $plant^{-1}$, number of filled grains $head^{-1}$ and grain weight $plant^{-1}$ respectively.

Munir (2007) reported that studies were conducted for two consecutive years of 2004 and 2005 at the research area of Agronomy Department, University of Agriculture, Faisalabad, Pakistan to assess the comparative productivity of sunflower to integration of manure and nitrogen application. Integration of organic and inorganic fertilizers compared of Treatment were: control (no fertilizer), farm yard manure @ 20 t ha^{-1}, poultry manure @ 8 t ha^{-1}, @ 100-75-50 NPK kg ha^{-1}, @ 75-75-50 NPK kg ha^{-1}, @ 50-75-50 NPK kg ha^{-1}, 25-75-50 NPK kg ha^{-1} alone and combined. Munir (2007) reported that Maximum seed yields of 2895 kg ha^{-1} and 2792 kg ha^{-1} were obtained with the treatment of 50-75-50 NPK kg ha^{-1} + PM at 8 t ha^{-1} during both years, respectively. Inorganic fertilizers @ 100-75-50 NPK kg ha^{-1} produced relatively more seed yield than organic manures (FYM @ 20 t ha^{-1} and PM @ 8t ha^{-1}) and PM gave higher yield than FYM. All the quality traits were significantly differ by the various combinations of organic and inorganic fertilizers.

2.4.6 Effect of poultry litter on the growth and yield of crops

Agbede *et al.* (2017) reported that a field experiment was conducted in the forest-savanna transition zone of Nigeria from May to July 2014 and September to November 2015 to determined the impacts of poultry manure (PM) and NPK fertilizer on soil physical properties, and growth and yield of carrot (*Daucus carota* L.). The five treatments included no manure or fertilizer (control); 10, 20 and 30 mega grams (Mg) ha^{-1} of PM; and 300kg ha^{-1} of 15 N-15 P- 15 K fertilizers. Plant height, number of leaves, root diameter, root diameter, root length, and fresh root yield in the PM and NPK fertilizer treatments were improved compared to the control. Growth and yield parameters of carrot plants treated with 20 and 30 Mg ha^{-1} PM were higher than the other treatments. The 20 Mg ha^{-1} PM treatment best improved soil properties and carrot productivity as indicated by the benefit-to-cost ratio.

Karim *et al.* (2013) reported that a field study was carried out at the experimental farm of the Department of Genetics and Plant Breeding, Bangladesh Agriculture University, Mymensingh during the period from July to November 2011. To evaluate the effect of cow dung and poultry manure with chemical fertilizer on the yield and quality of soybean *cv.* BINA soybean-2. The experiment was laid out in randomized complete block design having 9 treatments *viz.* control (CT), three levels RDCF 100%, 75% and 50%, three levels cow dung 10, 5, 3 t ha^{-1}, three levels poultry manure 3, 1.5, 1.0 t ha^{-1}, alone and their combinations, respectively. All the treatments significantly influenced the yield, yield attributing parameters and protein and oil content of BINA soybean-2. The highest plant height, yield, branches $plant^{-1}$, filled pods $plant^{-1}$, grain $plant^{-1}$ and 100-grain wt. were found in RDCF 100%, which were statistically identical with RDCF 75%+CD 3 t ha^{-1} and the lowest values of all the parameters were obtained from control treatment. The overall finding of this study indicated that organic manure in combination with the recommended dose of chemical fertilizers could be applied to be achieve better yield and quality of soybean as well as to improve soil fertility status.

Uddin *et al.* (2018) reported that a pot experiment was carried out to evaluate the integrated effects of poultry litter, nitrogen and phosphorus on the growth and micronutrient (Fe, Zn and Cu) contents of arum (*Colocasia esculenta* **L.**) in the net house of the Department of Soil, Water and Environment, University of Dhaka. There were fifteen treatments, three levels of poultry manure (0.0, 2 and 4 t ha^{-1}, three levels of N (0.0, 20 and 40 kg ha^{-1} and three levels of P (0.0, 15 and 30 kg ha^{-1}, respectively comprises the treatments. Height (76 cm), leaf number (5 no. $plant^{-1}$), leaf area (1045.66cm $plant^{-1}$) and fresh (130.7g $plant^{-1}$) and dry (14.35 g $plant^{-1}$) weights of leaf, stem, bulb and root were achieved highest in the combined application of decomposed poultry litter compost and nitrogen ($PL_2N_{40}P_0$). The leaf area, and fresh and dry weights of leaves, stem, bulb and root varied significantly ($p< 0.05$).

Akon *et al.* (2018) reported that a pot experiment was carried out to the evaluated the effects of various organic manures on the growth performance and biomass production of *Gynura procumbens* in the net house of the Department of Soil, water and Environment, University of Dhaka. Seven types of manures, *viz.* ACI, BGF-1, Mazim, vermicompost, sufola, GTS, and poultry litter composts were used separately at the rate of 15 ton/ha. Highest height (78cm) in poultry litter compost, leaf number (208.33 no./plant) in sufola manure, leaf area, and fresh and dry weights of leaf varied significantly ($p \leq 0.05$) increased with time. Results showed that the overall best growth performance was achieved in poultry litter compost.

Moyin-Juse (2019) reported that a field experiment was carried out in Akure in the rain forest zone of Nigeria to determine the effect of poultry manure, wood ash and rice bran on the soil fertility improvement, growth and head yield of cabbage (*Brassica oleraceae* **L**.) in 2011 and 2012 cropping season. There were three organic fertilizers treatments, namely poultry manure, wood ash and rice bran, applied at 6 t ha^{-1} with a reference treatment NPK $_{15-15-15}$ fertilizer applied at 300 kg ha^{-1} and control treatment (no fertilizer). The experiment was arranged in a randomized complete block design with replicated three times. The results showed significant increases ($P < 0.05$) in the growth and head yield parameters of cabbage crop under the different organic fertilizers compared to the control treatment. The application of poultry manure resulted in the highest values of cabbage plant height, stem girth, leaf number, leaf area head weight, head length and head girth followed by NPK $_{15-15-15,}$ wood ash and rice bran, respectively. Cabbage head weight, head girth, head length, plant height, stem girth, leaf number and leaf area increased by 17, 18, 8, 17, 19, 10 and 16 %, respectively, with application of poultry manure compost to NPK fertilizer.

Hammad *et al.* (2011) reported that a study carried out at the Adaptive Research Farm Karor, Layyah Pakistan, to influence of different organic manures on wheat productivity. A spring wheat cultivar was used in an experiment. In these experiment five organic manures were used; green manure (GM), farmyard manure (FYM), poultry litter (PL), press mud (PM) and sewage sludge (SS). Manure was used at the rate of 10 t ha^{-1}. Six different treatments were made with different combination of these manures along with one treatment having recommended dose of NPK (150, 115, 60 kg ha^{-1} NPK, respectively and one control treatment with no fertilizer at all. The results indicated that the combination of GM+PL+SS each @ of 10 t ha^{-1} gave maximum economic yield (3.65 t ha^{-1}), which was 137% more from control. PL and SS each @ 10 t ha^{-1} followed by green manure should be use as organic manure in wheat crop.

A field experiment was conducted the field in two villages (Oniyo and Moloko Ashipa) representing two agro ecologies in the south west of Nigeria during 2000 and 2001 cropping seasons. The objectives of the study were obtained to determine the effects of NPK fertilizer and poultry manure on the yield and yield components in cassava/ maize/melon system. The factors responsible for the study were (1) cropping system: cassava/maize/melon system, sole cassava, sole maize and (2) fertilizer: no fertilizer, NPK 15-15-15 from poultry manure and mineral fertilizer (NPK 15-15-15). It was found that crop yields were increased significantly P< 0.05) with NPK+ poultry manure than either NPK alone or control (Ayoola and Adeniyan, 2006).

Fallah *et al.* (2007) conducted an experiment during 2004 in Iran, to undertaken the effects of manure incorporation methods and integrated effect of poultry manure with chemical fertilizers on the grain yield and yield components of maize. Incorporation of fertilizer with soil by furrower or disk was observed in the main field. The sub plot consisted: control (no consumption of fertilizer and poultry manure), Five levels of NPK *viz.* N: P: K: 200:100:100 kg ha^{-1}, 80, 60, 40 and 20% kg ha^{-1}, NPK of main dose. Five levels of poultry manure (PM) *viz.* 4, 8, 12, 16 and 20 t ha^{-1}. The chemical fertilizer and organic manure were applied alone and combine. It was found from the inference that plant height, 1000 seed weight and grain and biological yields significantly increased with incorporation of fertilizer furrower, compared with disk. However, there were no significant differences in the number of seeds per year and harvest index between the two fertilizer incorporation methods. Fertilizer treatments significantly increased yield characteristics except for harvest index. Effectiveness of integrated poultry manure and chemical fertilizer on maize yield components was higher than the only effect of single fertilizer application.

Ayoola and Adeniyan (2006) reported that a field study was driven in two villages (Oniyo and Moloko Ashipa) representing two agro ecologies in the south west area of Nigeria during 2000 and 2001 cropping seasons. The objectives of the study were to examine the effects of NPK fertilizer and poultry manure on the yield and yield components in cassava/maize/melon system. The factors responsible for that were (1) cropping system: cassava/maize/melon system, sole cassava, sole maize and (2) fertilizer: no fertilizer, NPK 15-15-15 (400 kg ha^{-1}), poultry manure (5 t ha^{-1}), 2.5 t ha^{-1} +200 kg ha^{-1} NPK 15-15-15 and mineral fertilizer (NPK 15-15-15). It was found that crop yields were increased significantly with the NPK + poultry manure than either NPK alone or control.

Yield and quality of cowpea were increased by an integrated effect of poultry manure and inorganic fertilizer. A study on the effects of poultry manure and inorganic nitrogen fertilizer on the grain yield and proximate composition of two cultivars of cowpea (If brown and IT 86D-719) was carried out in Ile-Ife, Nigeria, during 1998. They showed cultivars in a randomized complete block design laid out in a split plot arrangement and treated with 4 sources of fertilizer (inorganic fertilizer (IF), mixture of inorganic fertilizer and poultry manure (IFPM), poultry manure (PM) and no fertilizer or manure treatment or control (C). Each fertilizer source supplied 20 kg N ha^{-1} the effect of yield and yield component and proximate of both the cultivars were significantly higher than control. The crude protein, percentage of crude fiber, total nitrogen and carbohydrate contents were composition clearly highest with poultry manure and inorganic fertilizer treatment (Amujoyegbe and Alofe, 2003).

Latthif and Maraik**a**r (2003) conducted an experiment commencing in the maha season of 1999-2000, on a raddish brown latosolic soil, at Gannoruwa in the mid country wet zone of Srilanka to study the performance of different vegetable crops when grown as a mono crop and as mixed crops under an organic farming system. Cattle manure (CM) and poultry manure (PM), applied at the rates of 20, 30, 40 and 10, 20, 30 t ha^{-1} were the only source of nutrients for the crops. For comparison, a chemical fertilizer treatment, using recommended quantities of NPK, was included in all experiments conducted. In the mono crop experiments, aubergine, cabbage and tomato gave higher yield when treated with manure with NPK. In the mixed crop experiments, where the performance different combination of bush bean, cabbage, capsicum, carrot and knol khol (*Brassica oleracea var. gongylodes*) were tested, there was no significantly yield increase with the increasing rates of cattle manure, but there was significant difference between yield obtained with poultry manure at 10 and 30 t ha^{-1}. Poultry manure also enhances soil quality and olsen P content.

Gani (2014) reported that two field experiments were carried out at Manikgonj and Kishoreganj district of Bangladesh to find out the impacts of poultry litter on soil properties and production of jute. Experiments were laid out in randomized complete block design having nine treatments with three replications. Poultry litter was applied in four levels: 25, 50, 75 and 100% RDF equivalent to 100% N from PL. NPK fertilizers were applied in four levels: 25, 50, 75 and 100% RDF. The treatments were arranged alone and combination to each other and control (without organic and inorganic fertilizers). Results showed that the highest uptake of N, P, K and S were found 272.60, 64.78, 275.52 and 23.28 kg ha^{-1}, respectively with the integrated treatment T_9 (RDF N 100% from PL + 100% RDF) at Manikganj. The highest content of N (2.56%), P (0.56%), K (2.57%) and S (0.073%) were found with T_9 (RDF N 100% from PL + 100% RDF) over the control at Keishoreganj. The highest growth and yield parameters *viz.* plant height, base diameter, yield of fibre and stalk were obtained with the integrated treatment T_5 (RDF N 50% from PL + 50% RDF). Total dry matter production was significantly superior with T_7 (RDF 75% from PL + 25% RDF).

2.4.7 Economic use of poultry litter and NPK fertilizers

Basavaraju and Purushotham (2009) reported that 50 per cent N through FYM + 50 per cent NPK through fertilizer in finger millet recorded higher B: C ratio (2.03) as compared to recommended N with available P and K through vermicompost (1.08). Another research revealed that the net return in soybean was significantly higher with combined application of organic and fermented liquid manures over no fermented liquid manures.

From the above literatures, it is clear that the combination of poultry manure and NPK fertilizers are more suitable than chemical fertilizers alone or poultry manure alone for sunflower and other crops production and increase soil physical, chemical and biological properties and improved soil health by increasing organic matter and plant nutrients and reduce environmental hazards.

2.5 Vermicompost as a source of fertilizer

A process related to composting which can be improving the beneficial utilization of organic wastes is composting. It is a non-thermophilic process by which organic materials converted by earthworm and microorganisms into rich soil amendments with greatly increase microbial activity and nutrient availability (Norman *et al.*, 2005).

The literature reviewed of earlier workers has been reviewed on the utilization of vermicompost in the production of sunflower and other crops and its effect on soil properties were given bellow:

2.5.1 Effect of vermicompost on physical properties of soil

Edwards and Burrows (1988) reported that vermicompost are finely divided peat- like materials with high porosity, aeration, drainage, water holding capacity (Norman *et al.*, 2005). Vermicompost are leading to bi-oxidation and stabilization of organic material. Vermicompost are effective organic fertilizer and bio-control agent (Edwards and Arancon, 2004). Norman *et al*. (2005) reported that the new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, bulk density, soil aeration, soil color, soil temperature, porosity, water holding capacity, increase plant growth promoting factors. For these reasons root penetration properly that plant can get mechanical support, enhance soil fertility and increase crop yields. Mondal *et al*. (2017) reported that the eco-friendly and environmentally safe bio-fertilizer, vermicompost, etc. become handy to minimize chemical fertilizer use as well as a carbon sink such crop field. In recent years, vermicomposting has turned out to be promising way out for safe disposal of organic waste. It is a technique of biodegradation or stabilization of organic waste (natural/anthropogenic) by using earthworms and microbes (Mainoo *et al.*, 2009; Mondal *et al.*, 2017).

2.5.2 Effect of vermicompost on chemical properties of soil

There is the possibility of increasing the N content of compost by inoculation with N-fixing organisms, and the P content by the addition of rock phosphate and then inoculation with phosphate solubilizing bacteria, since direct application of rock phosphate is not useful, particularly in neutral and alkaline soil (Akbari *et al.*, 2011). Composting organic refuse with rock phosphate and microbial activities may help to solublize phosphorus and to increase phosphorus availability to plants. Nitrogen fixing bacteria, besides fixing N, solubilize P due to production of organic acids and enzymes (Kumar and Narula, 1999). Organic matter are an excellent source of plant available nutrients and their addition to soil could maintain high microbial populations and activities with increased values of biomass C, basal respiration, biomass C: total organic C ratio, and metabolic quotient, crop yields have increased with the corresponding improvements in soil quality from additions of organic matter. Vermicompost have greatly increased surface areas, providing more micro sites for microbial decomposing organisms, and strongly absorption and retention of nutrients (Shi-Wei and Fu-Zhen, 1991).

Albanell *et al.* (1988) reported that vermicompost tended to have P^H value near neutral that might be due to the production of CO_2 and organic acids produced during microbial metabolisms. Hangarge *et al.* (2004) reported that higher soil organic carbon content, lower P^H and E.C with the combined application of vermicompost at 5t ha^{-1} +liquid organics (cow dung slurry at 11 m^{-2} and organic booster at 1.01 m^{-2} against initial values after harvest of chilli when compared to absolute control.

2.5.3 Effect of vermicompost on biological properties of soil

Vermicompost has been decreased by several authors as humus like materials and the degree of humification has been investigated fairly thoroughly (Norman *et al.*, 2005). The humifying capacity of earthworms, in the production of vermicoppost was reported by Businelli *et al.* (1983) after *Lumbricus rubellus* processed a range of mixture: cow and rabbit dungs, cattle and horse dungs, cow and sheep dungs and municipal waste compost. Nair *et al*. (1997) compared the microorganisms associated with vermicompost with those in traditional composts. The vermicomposts had much larger populations of bacteria (5.7x107), Fungi (22.7x104) and actinomycetes (17.7x106) compared with those in conventional composts. The outstanding physicochemical and biological properties of vermicompost makes them excellent materials as additives to greenhouse container media, organic fertilizers or soil amendments for various field horticultural crops. The transformations into humic compounds by passage through the earthworm gut revealed that the rates of humification of ingested organic matter were intensified during earthworm gut transit. (Norman *et al*., 2005; Mondal *et al.*, 2017) reported that in the recent years, among the various sources of organic manure efficacy of vermicompost was reported manifold. Earthworms consume large quantities of organic matter and excrete it as cast and this cast contains several enzymes and is reach in plant nutrients, which are beneficial for bacteria and mycorhaizae (Reddy and Reddi, 2002). They also noted that vermicompost is an excellent base for the establishment of beneficial non-symbiotic and symbiotic microbes.

2.5.4 Effect of vermicompost on plant nutrients

The quality and quantity of the nutrients in vermicompost can be explained by accelerated mineralization of organic matter, break down of polysaccharides and a higher rate of humification achieved during vermicomposting (Elvira *et al.*, 1996; Albanell *et al.*, 1988).

In investigations into the bioconversion of solid paper-pulp mill sludge by earthworms, it was reported that carbohydrate content decreased while total extractable carbon, non-humified fraction and humification rates increased by the end of the experiment. Earthworm plays a major role in plant material degradation and this concept is use in vermicomposting technology with the supplement of cow dung source to enhance plant growth (Noman *et al.*, 2005; Mondal *et al.*, 2017). Application of vermicompost on sunflower crops can play a vital role to reduce heavy metal and radio nuclides. Heavy metal toxicity and the danger of their bioaccumulation in the food chain represent one of the major environmental and health problems of our modern society. Most common heavy metal contaminant are cadmium (Cd), Chromium Cr), Copper (Cu), Mercury (Hg), Lead (Pb), Nickel (Ni), and Zink (Zn). It also enhances quality of growing plants and increased biomass which could suggest that more metal can be taken up from the contaminated growth media and the tolerance to the metal toxicity is improve (Tang *et al*., 2003). Plants such as Indian mustard (*Brassica juncea*), corn (Zeamays L.) or sunflower (*Helianthus annus* L**.)** show high tolerance to heavy metals and therefore, are used in phyto remediation studies (Schmidt, 2003; Tang *et al*., 2003). Hangarge *et al*. (2004) reported that, the application of liquid organic cow dung urine slurry at 2 litter m^{-2} along with vermicompost at 5t ha^{-1} resulted in higher available N (353.00 kg ha^{-1}), P_2O_5 (21.00kg ha^{-1}) and K_2O 284.00kg ha^{-1}) after harvest of chilli than RDF (319.00, 18.00, 280.0kg N, P_2O_5 and K_2O, respectively). Elvira *et al.* (1996) reported that humification rates were increased significantly in paper pulp mill sludge work by *Eisenia andrei.* Orlov and Biryukova (1996) reported that VCs contained 17-36% of humic acid and 13-30% fulvic acid of the total concentration of organic matter. Edwards and Burrows (1988) reported that vermicompost especially those from animal waste sources, usually contained more mineral elements than commercial plant growth media, and many of these elements were changed to forms more that could be readily taken up by the plants, such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium. Orozco *et al.* (1996) reported that coffee pulps, increased the availability of nutrients such as P, Ca and Mg, after processing by *Eisenia fetida.* P was 64% higher in vermicompost than in the original organic material which was suggested to be due to increased phosphatase acidity form the direct action of gut enzymes and indirectly by the stimulation of microorganisms. Edwards and Burrows (1988) also reported large amounts of minerals in earthworm-processed animal waste compared with those in commercial compost. The wastes they investigated were separated cattle solids, separated pig solids, cattle solids on straw, pig solids on straw, duck solids on straw, and chicken solids on shavings. These materials contained mineral contents (% dry weight) ranging from 2.2-3.0 N, 0.4-2.9 P, 1.7-2.5 K and 1.2-9.5 Ca compared to those of a commercial plant growth medium (Levington compost) which only had 1.80, 0.21, 0.48 and 0.94 for N, P, K and Ca respectively.

2.5.5 Effect of vermicompost on sunflower growth and yield

Vadiraj *et al*. (1998) revealed that application of vermicompost in coriander (*Coriandrum sativum* **L.**) significantly increased herbage and seed yield as compared to chemical fertilizers. The herbage yield was maximum in Rcr-41 (6067.5kg ha^{-1}) at 60^{th} day after sowing when 15 t ha^{-1} of vermicompost was applied and seed yield was maximum in Rcr-41 (1314kg ha^{-1}) in plants treated with 20 t ha^{-1} vermicompost.

Baradhan *et al.* (2006) revealed that application of 50 per cent recommended dose of nitrogen fertilizer as urea along with 50 per cent N as vermicompost recorded the highest seed yield of 1140 kg ha^{-1} followed by FYM and bone sludge substitution with yields of 995 and 930 kg ha^{-1}, respectively in sunflower.

Byrareddy *et al.* (2008) reported that application of RDF + FYM @ 8t per ha was more effective in increasing the seed yield in KBSH-1 hybrid sunflower seed production followed by 50 per cent N (VC) + 50 per cent (urea) + SSP.

Application of only biogas slurry or vermicompost enhanced the vegetative and reproductive yield of sunflower but the highest yield was recorded with conjunctive use. Hence, this study revealed that application of biogas slurry and vermicompost could be undertaken to replace chemical fertilizers in the cultivation of organic sunflower (Ahmad and Jabeen, 2009).

Sharma *et al.* (2014) reported that a study the response of organic and inorganic nitrogen (N) sources both alone and in conjunction and their influence on soil quality, a field experiment was conducted during kharif and rabi seasons using sunflower (MSFH-8) as test crop. The experimental site soil was Typic Haplustaff situated at Hayatnagar Research farm of Central Research Institute of Dry land Agriculture, Hyderabad, India. The experiment design was a simple randomize block design with 11 treatments replicated four times. There were four levels of N (0.0, 25, 50 and 75 kg ha^{-1}), two levels VC (25 and 50) kg N ha^{-1}, two levels FYM (25 and 50) kg N ha^{-1}, and two levels glyricidia (25 and 50) kg N ha^{-1}, respectively. Among all the treatments, vermicompost (VC) +Fert at 25+25 kg N ha^{-1} recorded the highest grain yields during both rabi and kharif seasons. Conjunctive nutrient treatments proved quite superior to other set of treatments in improving the uptake of N, P, K, S and micronutrients in sunflower and their buildup in the soil. Considering the yield and relative soil quality indices (RSQI), conjunctive applications of VC with inorganic fertilizer, FYM, or Gly at 25+25 kg N ha^{-1} could be a successful and sustainable soil nutrient management practice in semi-arid tropical Alfisols. Beside this, the fertilizer N demand could be reduced up to 50%.

Godavari *et al.* (2017) reported that a field experiment was conducted at Oilseeds Research Unit Dr. P. D. K.V. Akola, during 2015-2016 using a Randomized Block Design with three replications along with seven treatments. The study was carried out with specific objectives of higher moisture retention and slow release to tide over intermittent drought in Kharif and growth and yield of sunflower. Two levels of farm yard manure (FYM) @ (2.5 t ha^{-1}, 5 t ha^{-1}), Vermicompost (VC) @ 2.5 t ha^{-1}, Fly ash @ 2.5 t ha^{-1}, hydrogel @ 2.5 kg ha^{-1}, humic acid @ 2.5 kg ha^{-1} and RDF (80:60:30). Those were used with RDF and RDF alone. The result showed that growth parameters *viz.* plant height, head diameter, seed yield and 100 seed weight varied significantly due to use of moisture retentive material on sunflower. Application of 100 per cent RDF with vermicompost @ 2.5 t ha^{-1} recorded highest plant height, head diameter, 100 seed weight, seed yield and oil yield except oil content which was at par with each other.

Kademani *et al.* (2003) reported that a field experiment was conducted in Vertisol at Water Management Research Centre, Belavatagi in Malaprabha Command during rabi 1999-2000 to study the integrated effect of organic and inorganic sources of nutrients on uptake of nutrients by sunflower and their availability after harvest. The organic sources included were maize residue, cotton stock, FYM each @ 5 t ha^{-1} and vermicompost @ 2 t ha^{-1}. The inorganic fertilizer levels were 0, 50, 75 and 100% recommended dose of fertilizer. The highest uptakes of NPK were recorded in vermicompost treatment followed by FYM, cotton stock and maize residue. Available N, P, K, and S in soil at harvest of sunflower crop were recorded highest with application of vermicompost @ 2 t ha^{-1} followed by FYM. Among the fertilizer levels, 100 per cent RDF has given higher available N, P, K and S than at lower levels of fertilizer.

2.5.6 Effect of vermicompost on the growth and yield of crops

Edwards and Burrows (1988) reported that vermicompost increased ornamental seedling emergence compared with those in control commercial plant growth media, using a wide range of test plants such as pea, lettuce, wheat, cabbage, tomato and radish.

Buckerfield *et al.* (1999) reported that vermicompost applications inhibited germination initially, but subsequently weekly applications of the diluted extracts improved plant growth and increased radish yields significantly by up to 20%. The growth of tomatoes, lettuces, and peppers were reported to the best at substitution into soils at rates of 8-10%, 8% and 6%, respectively, using duck waste vermicompost and peat mixture. Research at the Soil Ecology Laboratory, of The Ohio State University has shown consistently acceleration of germination of a wide range of crops by vermicompost.

Rakesh *et al.* (2013) further reported that fat content (%) in the four treatments such as VC @ 5t ha^{-1}, 10t ha^{-1}, 20t ha^{-1} and NPK (recommended) showed a significant increase 1.0, 1.1, 1.2 and 1.25 respectively, as compared to control 0.97 (no fertilizer) in *Triticum aestivum* **L.**

Patil *et al.* (2008) studied the effects of use of manures and fertilizers alone and in combination on soybean and concluded that highest amounts of grain and straw yield and crude protein recorded by conjoint use of manures and fertilizers.

Subler *et al.* (1998) reported that increased plant growth in commercial media, Metro-Mix (MM360), with a range of vermicompost of substituted compared to growth in traditional composts from bio-solids and yard waste traditional composts using tomatoes and marigolds as test plants. Metro- Mix 3360 is prepared from vermiculite, Canadian sphagnum peat moss, barks ash and sand, and contains a starter nutrient fertilizer in its formulation. In Subler's experiments, increases in chlorophyll contents in response to vermicompost were observed at early stages of marigold growth. Later, increases in leaf areas and significant increases in the total plant weights were reported in 10% vermicompost and 90% Metro Mix 360 combinations compared with 100% MM360. Significant increases in tomato seedling weights after substitution of 10% and 20% vermicompost into MM3360 were also reported.

Sustainable nutrient management with the combination of organic and chemical fertilizer amendment expects a key part in upgrading stevia yield. In these regard, Zaman *et al.* (2018) a pot experiment was conducted in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh to study the combined effect of vermicompost (VC) and chemical fertilizer (CF) on the growth, leaf biomass yield and stevioside content of stevia in acid soil. As basal doses, N, P, K, S, Zn and B fertilizers were applied as rates of 250, 100, 200, 30, 3 and 1 kg ha^{-1}. Six combinations of VC and CF were applied following completely randomized design (CRD) with three replications. They used three levels of VC (0.0, 5.0 and 7.5 t ha^{-1}) and four levels of CF (0.0, 50, 75 and 100%). These doses were used in six combined dosed and among that one was control (no VC and CF). Results showed that VC along with different rates of CF exerted significant influence on the growth, leaf biomass yield and stevioside content of stevia and post harvest soil fertility. The highest values of most parameters were found in the treatment, VC @ 7.5 t ha^{-1} + 50% CF. Soil acidity was significantly decreased with the increased levels of VC and CF where as soil fertility in terms of organic matter and nutrient content was increased. The highest N, P, K and S uptakes were found in the treatment of VC 7.5 t ha^{-1} + 75% CF. Considering the overall performance, farmers may be advised to cultivate stevia in acid soil applying VC @ 7.5 t ha^{-1} + 50% chemical fertilizer, to boost up stevia production under the agro-climatic condition of the study area in the context of Bangladesh.

Suther (2009) reported that an experiment was conducted in an agriculture plot situated in Bhakhra canal belt of Tibbi village, Hanumangarh, India to impact of vermicompost and composted farmyard manure on growth and yield of garlic as field crop. The experiment was conducted for two subsequent cropping years during 2000-2002, in the same experimental field. There were six treatments *viz.* recommended dose of NPK, 15 t ha^{-1} VC, 20 t ha^{-1} VC, 15 t ha^{-1} VC + 50% NPK, 15 t ha^{-1} FYM, 15 t ha^{-1} FYM + 50 % NPK, respectively. The maximum range of some plant parameters i.e. root length, shoot length, leaf length, fruit weight, number of cloves in garlic fruit and number of leaves per plant was in the treatment, 15 t ha^{-1} VC + 50% NPK. The average fruit weight was approximately 26.4% greater in 15 t ha^{-1} VC + 50 % NPK than recommended NPK treatment. This study suggests that vermicomposted manure may be a potential source of plant nutrients for sustainable crop production.

Joshi *et al*. (2013) conducted field experiments in the Botanical Garden of Guru Nanak Dev University to grow wheat in a two year field trial during Nov- April 2008-09 and 2009-10. Five treatments were given *viz.* Soil (control), VC@5 t/ha, VC@10 t/ha, VC@20 t/ha and NPK (recommended by PAU, Ludhiana) in triplicates in a Randomized Block Design (RBD). A total of 50 plants were selected randomly for the assessment of growth and yield of wheat (*Triticum aestivum* **L.**). Most of the growth, yield and quality parameters were found maximum in NPK treatment. All the growth, yield and quality parameters in vermicompost treatments varied significantly from control though differences within various vermicompost treatments were not found to be significant. Protein content (%) and fat content in al the four treatments were observed to be significantly higher than control.

Mondal *et al.* (2017) reported that a study the impact of reduced dose of chemical fertilizer and its combination with bio-fertilizer and vermicompost on morpho- physiological and biochemical traits of mustard (*Brassica campestris cv.* B9). Field experiments were conducted during winter seasons of November to February 2011-2012 and 2012-2013 respectively in an old alluvial soil zone of Crop Research and Seed Multiplication Farm, Burdwan University, Burdwan, west Bengal, India. Mustard was cultivated using a full recommended dose of chemical fertilizer (N: P: K-100:50:50) and with six different reduced doses of chemical fertilizer combined with bio-fertilizers and vermicompost. The treatments were arranged in a randomized block design (RBD) with three replications. The performance of the crop was adjudged in terms of various parameters *viz.* leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR), crop growth rate etc of mustard. Differential significant ($P<0.05$) treatment response was reflected for the studied traits during crop maturity. The data revealed that vermicompost application significantly stimulated most of the studied attributes. It was concluded that 25% reduced dose of chemical fertilizer and its combination with vermicompost was optimum for most of the parameters studied as compared to the control at both crop stages.

2.5.7 Economic use of vermicompost and NPK fertilizers

Godavari *et al*. (2017) reported that highest gross (Rs. 42266 ha^{-1}), net monetary returns (Rs. 24475 ha^{-1}) and B: C ratio (2.38) of sunflower seed was recorded in RDF + vermicompost @ 2.5t ha^{-1} in seed furrows followed by application of 100% RDF with hydrogel. The lowest gross returns, net returns and B: C of the recommended fertilizer dose with application of vermicompost might be due to higher sunflower seed yield coupled with higher market price.

Byrareddy *et al*. (2008) reported that the maximum benefit: cost ratio was realized with the application of RDF + FYM 8 t ha^{-1} (5.9) followed by 50 per cent N (1.1t ha^{-1} VC) + 50 per cent (urea) +64.50 kg ha^{-1} P_2O_5 (SSP) (5.8), while the least B: C ratio was recorded with control (1.7) of sunflower seed.

2.6 Role of NPK on the growth and yield of sunflower

The combined use of nitrogen, phosphorus and potassium in balanced share at proper time has great impact on sunflower and other crops yield. Plant species, even varieties with in species vary in their behavior to obtain and utilize nitrogen, phosphorus and potassium for grain production (Malghani *et al.*, 2010). As the history indicates that there is a sever shortage of edible oil seeds in Bangladesh that can hardly accumulate the requirements. To meet the needs of population and never-ending rise in urbanization has led to broaden the gap between local availability and requirement to increase in number of mouths as well as rise in per capita consumption (Nasim *et al.*, 2012).

Phosphorus insufficiency is common in most of the soils of Bangladesh and application of phosphatic fertilizer is considered crucial for production. Phosphorus stimulates flourishing and seed formation. Its deficiency is direct related with 1000 grains weight. Potassium (K+) is of unusual significance because of its live role in biochemical functions of the plant like activating various enzymes, improvement of protein, carbohydrates and fat concentration, developing tolerance against drought and resistance to frost, lodging, pests and disease attack**.** The increase in intensive of cropping and production of high yielding fertilizer responsive cultivars has resulted in a considerable deplete of soil K reserves and eventually limits efficiency of other nutrients. It is thus necessary to divide a fertilizer technology, facilitating use of NPK in apt combination for enhancing crop yield (Malghani *et al.*, 2010). Different levels of nitrogen significantly influenced LAI, total dry matter accumulation, CGR, although, plant height was not significantly influenced by the different levels of nitrogen application. On the other hand, increased crop growth and development rates and greater biomass accumulation in well fertilized crops would also correlate with decreased allocation of resources toward the production of starch, cellulose and non-nitrogen containing secondary metabolism, important group of bioactive compounds (Mondal *et al.*, 2017). The ability to assimilate nutrients during the growth period is important for yield and quality development in plants. In sunflower oil quality and yield are both dependent on plant genotype and its interaction with environment (Li *et al*., 2017). Among the factors responsible for increasing crop yield and quality, fertilizer use is one of the most important (Reddy *et al*., 2003).

Of all the nutrients in fertilizers nitrogen is the most important for enhancing metabolic processes based on proteins and leads to increases in vegetative growth, reproductive growth, and yield of the crop (Koutroubas *et al*., 2008). Sunflower responds well to applied nitrogen and the fatty acid composition of sunflower seed oil in five cultivars can be improved by manipulating the nitrogen supply rate and the time of nitrogen application in both glass house and field experiments (Steer and Seiler, 1990).

Hence, balanced fertilizer application is important for high crop yield and consequently more oil yield. Crop yield is frequently constrained by the availability of major nutrients, including N and P. While approaches for the diagnosis and management of crop nutrition often target individual nutrients, there is an increasing interest in integrated nutrient management. Fertilizer application represents an important measure to correct nutrient deficiency and to replace elements removed in the products harvested, and has been shown to be particularly effective with respect to yield formation. However, recovery of fertilizer N is often as low as 50%, which has serious ecological consequences. Significant responses of seed oil yield to an increased level of NPK fertilizers have been observed by several investigators (Rathke *et al.*, 2006; Bakht *et al.*, 2010). Judicious use of fertilizer is considered one of the most important factors which could increase sunflower yield on per unit area bases (Sadiq *et al.*, 2000). Among nutrient applied, K is one of the most essential elements for plant growth. Its role is well documented in photosynthesis, enzyme activity, synthesis of protein, carbohydrates and enabling to resist against pest and diseases (Sadiq *et al*., 2000). Nitrogen is an essential element and important determinant for plant growth and developed. It is the second most required nutrient for the culture of sunflower. Metabolic processes leading to increases in vegetative and reproductive growth and yield are totally dependant upon the adequate supply of nitrogen. Potassium is a nutrient that positively affects achenes production within sunflower crop (*Helianthus annus* **L**.) and its proper management is indispensable for better economical employment of this element for a less environmental impact (Chaves *et al.*, 2014). Nutrients play an important role in crop growth and development. Among the nutrients, N is one of the major nutrients that enhance the metabolic processes that based on protein, leads to increases in vegetative, reproductive growth and yield of the crop (Nawas *et al.*, 2003; Bakht *et al*., 2010 and Nasim *et al*., 2012). In news, reclaimed soil plant nutrients (especially N and K) are essential for crop production, it must be apply in proper quantities and at appropriate times, to help in achieving optimal crop yields. However, improper applying of plant nutrients can cause many agricultural and environmental problems. In addition, the availability and plant uptake of nutrients under new reclaimed soil are very difficult (Sadiq *et al*., 2000) to accurately quantifying the optimum potential environmental impact (Mahrous *et al*., 2014). It reported that optimum application of manure with NPK increased head size, plant height, 1000 seed weight and seed yield of sunflower.

2.6.1 Effect of NPK on crops productivity, soil health and sound environment

Application of chemical fertilizer has conducted significantly to the huge increase in the world food production, but the adverse impacts of excessive inputs of chemical fertilizations in conventional agricultural practices are being well documented (Garai *et al.*, 2014). Chemical fertilizers also have contributed significantly toward the pollution of water, air and soil. In agro- ecosystems, the use of synthetic toxic chemical pesticides affects the soil fertility and growth of cultivated crops (Ignacimuthu and Vendan, 2007). At present, we are using chemical fertilizers in great quantities to compensate the deficiency of nutrients in soil. For minimizing the accumulation of pollutants in agro- ecosystems, we should avoid the use of toxic chemicals especially synthetic chemical pesticides and fertilizers in agricultural process. However, this technique is not really efficient because it is too slow due to the low phyto-availability of metals in soil (McGrath *et al*., 2002)**.** Most of the Brazilian semiarid soils are characterized by the low availability of nitrogen and phosphorus, and this failure is usually corrected by using high doses of mineral fertilizers which is considered an economically and environmentally unsatisfactory solution. For these reasons, the search for alternative sources of fertilizer has increased, which are less harmful to the environment and economically efficient at the same time. Thus, to produce sunflower in semi-arid climate, it is necessary to seek for alternatives that regard the need of obtaining high productivity at a low cost, while using organic sources in a rational way, reducing the environmental impact of agriculture. Excessive N fertilization of sunflower not only generates that environmental risk, it may also affect the grain quality, decreasing its oil content and reduce yield through an increase of plant lodging (Scheiner *et al*., 2002; Akbari *et al*., 2011). The selection of manure management and treatment options increasingly depends on environmental regulations for preventing pollution of land, water and air (Akbari *et al*., 2011). In this field, many experiments were conducted to study the effect of manures alone or in combination with other chemical fertilizers (Ram Rao *et al*., 2007). Sunflower hybrid gave a higher yield from a combination of organic manures with chemical fertilizer (Dayel and Agarwal, 1998; Akbari *et al*., 2011). Sunflower responds well to applied nitrogen as chemical fertilizer. The fatty acid composition of sunflower seed oil in five cultivars can be improve by manipulating the nitrogen supply rate and the time of nitrogen application in both glass house and field experiments (Steer and Seiler, 1990). However, the use of N fertilizer is associated with economic and environmental risks, especially when N fertilizer management strategies are poor (Sylvester-Bradley, 1993). Although excessive inorganic fertilization can generate environmental hazard, it may also affect sunflower grain quality and decrease its oil content. Significant reduction of sunflower yield through an increase in biomass is another effect of inorganic fertilizer over use (Shoghi-Kalkhoran *et al*., 2013). Excessive N fertilization of sunflower not only generates that environmental risk, it may also effects the grain quality, decreasing its oil content and reduce yield through an increase of plant lodging (Akbari *et al*., 2011). The use of chemical fertilizers has disadvantaged in the context of nutrient supply, crop growth and environmental quality. Intensive faming practices to produce high crop yields and quality require using large amounts of fertilizers. Therefore, the excessive use of mineral fertilizers is undesirable because of the chemical application leads to diverse environmental, agricultural, health consequences, and enhance the decomposition of soil organic matter, moreover, nutrient are easily lost from soils through fixation, leaching or gas emission and can lead to reduced, fertilizer efficiency. On the other hand, the production of chemical fertilizers is costly process. In addition, most of the energy for fertilizers production is provided by the consumption of non-renewable fossil fuels (Akbari *et al*., 2011; Mahrous *et al*., 2014). Farmers also use mineral fertilizers whose greatly increased crop yield. The use of mineral fertilizers report to increase yield and in the long term leads to decreasing base saturation and acidification of soil. In particular, the use of mineral fertilizers on continuous basis in tropical soil has been associated with reduced crop yield, increased soil acidity and nutrient imbalance (Agele and Taiwo, 2013). Agriculture plays an important role in economy of developing countries like Bangladesh. However, rapid crop production with in appropriate farming practices deteriorate organic matter in soil, which results in decreased microbial activity that eventually affect its physical, chemical and biological conditions which leads to decline in land productivity and crop yields (Badar and Qureshi, 2014). To solve this problem, synthetic fertilizers were always thought to be a better way to improve the soil fertility and crop productivity but unfortunately, the excessive use of these creates a number of serious environmental and health risk (Savci, 2012). To minimize these hazards, naturally occurring organic fertilizers, animal and plant manures, fall residues, and food and urban wastes are better alternate of commercially available fertilizers. Reports proved that organic farming improves soil composition, fertility, and soil fauna whose have a beneficial effect on crop production in the long run (Badar and Qureshi, 2014).

2.6.2 Combined effect of NPK and organic manures on plant growth and improve of soil eco-system

Considering the environmental and health problems arising from chemical fertilizers usage, many attention has been directed towards the application of organic farming to avoid the heavy use of agro-chemicals that result in enormous environmental trebles, the organic fertilizers have emerged as a promising component of integrating nutrient supply system in agriculture. These systems depend in many important ways on microbial activities, which appear to be a tremendous potential for making use of manures in increasing crop production (Mahrous *et al*., 2014). There is also a positive interaction between the organic manures and urea as nitrogen source (Munir, 2007; Bocchi and Tano, 1994). Sunflower hybrid gave a higher yield from a combination of organic manures with nitrogen and phosphorus (Dayal and Agarwal, 1998; Munir, 2007). The highest seed and stalk yield was recorded in sunflower with application of poultry manure as compare to other organic manures (Vanaja and Raju, 2003; Munir, 2007). The effects of different source of organic manures and chemical fertilizers alone or in combination on yields and seeds quality of sunflower as affected by water stress in eastern region of Iran (Esmaeilian *et al.*, 2012). Most of the Brazilian semiarid soils are characterized by the low availability of nitrogen, phosphorus and this failure is usually corrected by using high doses of mineral fertilizers (Filho *et al*., 2013), which is considered an economically and environmentally unsatisfactory solution. For these reasons, the search for alternative sources of fertilizer has increased, which is less harmful to the environment and economically efficient at the same time. Thus, to produce sunflower in semi-arid climate, it is necessary to seek for alternatives that regard the need of obtaining high productivity at a low cost, while using organic sources in a rational way, reducing the environmental impacts of agriculture (Filho *et al*., 2013). Extensive affords are necessary to improve soil hydro-physical properties as well as its productivity through application of fertilizers (Shoghi-Kalkhoran *et al*., 2013; Helmy and Ramadan, 2009). Fertilizers can improve soil structures and fertility by motivating biological activity and enhancing phosphorus solubility in soil. Fertilizer is one of the major factors that could increase sunflower production per unit area (Hailu *et al*., 2008).

Several investigators showed the effect of mineral and organic fertilizers application on sunflower as (Mahrous *et al.*, 2014). Different organic nutrient management practices have been found to be technically and financially beneficial, but they differ considerably as to their effectiveness and resource requirements. Adding nutrients in the form of organic fertilizers has many advantage, they enhance soil biological mobilization, enhance root growth due to better soil structure, release nutrients slowly and contribute to the residual pool of organic N and P in the soil. Also using organic fertilizers reducing N leaching loss and P fixation; they can also supply micronutrients, increase the organic matter content of the soil, therefore improving the exchange capacity of nutrients, increasing soil water retention, promoting soil aggregates (Place *et al.*, 2003). (Esmaeilian *et al.*, 2012; Chagas *et al.*, 2013) most of the Brazilian semiarid soils are characterized by the low availability of nitrogen and phosphorus, and this failure is usually corrected by using high doses of mineral fertilizers which is considered an economically and environmentally unsatisfactory solution. For these reasons, the research for alternatives effect that regard the need of obtaining high productivity at a low cost, while using organic sources in a rational way, reducing the environmental impacts of agriculture.

From the above literatures, it is clear that the combination of organic manures and NPK fertilizers are more effective than chemical fertilizers alone or organic manures alone for sunflower and other crops production and increase soil physical, chemical and biological properties and improved soil health by increasing organic matter and plant nutrients and reduce environmental hazards.

CHAPTER 3

3 MATERIALS AND METHODS

Experiments were conducted at the research farm of Charfasson Govt. College in Bhola, Bangladesh. The detailed research programme and methodology are presented in this chapter.

3.1 Location and description

The geographic location of the Bhola district is between 21^0 $51^/$ $28^{//}$ and 22^0 48 $^/30$ $^{//}$ north latitudes and 90^0 32 $^/$ $30^{//}$ and 91^0 $02^/$ $07^{//}$ east longitudes.

It has areas of 3737.21 km^2. It is bounded by Barisal and Laxmipur districts to the north, the Bay of Bangal to the south, by Laxmipur and Noakhali districts, the Meghna river and shahbazpur channel to the east, and by Patuakhali district and the river of Tentulia to the west. The Charfasson Govt. College situated about 68 kilometers south of the Bhola district head quarter. The total area of Charfasson is about 1106.31km^2 (BBS, 2016). The study area situated at 1.2 meters above the sea level. The cropping intensity is about 173.90% (Alam, 2007). The upazila bounded on the north by Lalmohon upzila, on the east by the River Meghna, on the south by the Bay of Bangal, on the west by the River Tentulia. General soil types include coastal saline soils. The morphology of the land is almost smoothly plain. The organic matter content is low to medium. Soils are deficient in N, P, K, S, B and Zn. Top soil pH ranges from alkaline to slightly acidic. It belongs to agro-ecological zone no.18, the young Meghna estuarine floodplain. The morphological characteristics of the study area are presented in Table 3.1.

Table 3.1 Morphological description of the study area

AEZ-18	Young Meghna Estuarine Floodplain.
Soil Series	Bhola.
Land Type	Almost smoothly plain.
Soil tract	Coastal floodplain soil.
Flood level	Normal.
Drainage	Moderate.
Vegetation	Different plant grown everywhere.

Source: Hussain (1992).

3.2 Climatic conditions

Table 3.2 Meteorological data during the crop growth period (Rabi, 2015-2016) at the research farm of Charfasson Govt. College, Bhola.

Months and years	Total rainfall (mm)	Mean relative humidity (%)	Mean air temperature (^{0}C)	
			Minimum	Maximum
December, 2015	03	85	15.8	26.4
January, 2016	01	83	12.7	25.8
February, 2016	31	76	19.0	30.2
March, 2016	08	77	22.3	33.3
April, 2016	51	79	26.6	34.7

Source: Bangladesh Meteorological Department, Regional office, Barisal, 2016.

Table 3.3 Meteorological data during the crop growth period (Rabi, 2016-2017) at the research farm of Charfasson Govt. College, Bhola.

Months and years	Total rainfall (mm)	Mean relative humidity (%)	Mean air temperature (^{0} C)	
			Minimum	Maximum
December, 2016	0.0	85	15.2	27.5
January, 2017	0.0	81	12.0	26.6
February, 2017	0.0	77	15.8	30.0
March, 2017	59.5	81	20.0	30.8
April, 2017	364.9	82	24.7	33.0

Source: Bangladesh Meteorological Department, Regional office, Barisal, 2017.

3.3 Collection of soil samples and analysis

A composite soil sample was collected from the field in first (2015-2016) and second (2016-2017) years. The soil was air dried, ground and sieved through a 0.5 mm sieve for chemical analysis and 2 mm sieve for physical analysis.

3.3.1 Physical properties of soil

3.3.1.1 Particle size analysis

Particle size analysis was done by hydrometer method (Bouyoucos, 1962).

3.3.1.2 Textural class

Textural class was determined by plotting the value sand, silt and clay to the "Marshall textural triangular co-ordinate" following the USDA system (Marshall, 1951).

3.3.1.3 Bulk density

Core sampler was used to collect the soil samples from 0-15cm depth to determine the bulk density. Precaution was taken to avoid compaction. The soil was trimmed to the exact volume of the core and oven dried at 105^0C for constant weight (Blake and Hartge. 1986).

3.3.1.4 Particle density

The pycnometer method was followed to determine particle density of soil as described by Blake and Hartge, 1986.

3.3.1.5 Maximum water retentive capacity

Maximum water retentive capacity of the undisturbed soil was carried out with help of a core sampler as described by Gardner (1965).

The maximum water retentive capacity of soils was determined by using a core sampling method. Particle density was determined by pycnometer method as described by (Blake and Hartge, 1986).

3.3.2 Chemical properties of soil

3.3.2.1 Soil pH

The glass electrode pH meter was used to determine pH of the soil (model HI 2211). The ratio of the soil and water in the suspension was 1: 2.50.

Table 3.4 Physical and chemical properties of the soil used (2015-2016) and (2016-2017) season

Characteristics	Values	Values	References
Particle size analysis	2015-2016	2016-2017	
Sand (%)	12.3	12.20	Hydrometer Method (Bouyoucos ,1962)
Silt (%)	54.34	54.34	
Clay (%)	36.36	36.46	
Texture	Silty clayey loam	Silty clayey loam	Marshall Textural Triangular Co-ordinate (Marshall, 1951)
Bulk density (g/cc).	1.34	1.45	Core Method (Blake and Hartge, 1986)
Particle density (g/cc).	2.31	2.48	Pycnometer Method (Blake and Hartge, 1986)
Maximum water retentive capacity (%)	37	40	Core Method (Blake and Hartge 1986)
PH	8.36	8.30	Glass Electrode P^H Meter (Hunter, 1984)
Organic carbon (%)	0.63	0.85	Wet Oxidation Method (Walkley and Black, 1934)
Organic matter (%)	1.12	1.46	Van Bemmelon Factor (Piper, 1942).
EC (d S m^{-1})	0.35	0.34	Conductometric Method (Jackson, 1958)
Total nitrogen (%)	0.40	0.47	Micro Kjeldahl Method (Marr and Cresser, 1983)
Available nitrogen (%)	0.24	0.27	Micro Kjeldahl Method (Marr and Cresser, 1983)
Available Phosphorus (%)	0.06	0.09	Vanadomolybdophosphoric Yellow Color Method (Jackson, 1958)
Exchangeable Potassium (%)	1.23	1.33	Flame Photometer (Extractable in *1N* ammonium acetate pH 7.0) (Pratt, 1965)
Available Sulfur (%)	0.15	0.13	Terbidimetric Method (Bardsley and Lancaster, 1965)
Copper (Cu) mg kg^{-1}	319.75	319.0	Atomic Absorption Spectrophotometer (AAS) (AOAC, 1990)
Zinc (Zn) mg kg^{-1}	104	105	(AAS) (AOAC, 1990)
Manganese (Mn) mg kg^{-1}	8.5	8.0	(AAS) (AOAC, 1990)
Chromium (Cr) mg kg^{-1}	7.1	6.9	(AAS) (AOAC, 1990)
Cadmium (Cd) mg kg^{-1}	ND	ND	(AAS) (AOAC, 1990)
Lead (Pb) mg kg^{-1}	5.0	4.9	(AAS) (AOAC, 1990)
Nickel (Ni) mg kg^{-1}	24.4	23.5	(AAS) (AOAC, 1990)

3.3.2.2 EC

Electrical conductivity was determined from the suspension using a conductivity bridge meter (model HI 2300) (Jackson, 1958). The ratio of the soil and water in the suspension was 1: 2.50.

3.3.2.3 Soil organic carbon

A known weight (0.5g) of 0.2 mm sieved soil was treated with a known excess volume of chromic acid ($K_2Cr_2O_7$+H_2SO_4). After oxidation of organic carbon present in soil, the untreated $K_2Cr_2O_7$ left in the content was back titrated agents standard $FeSO_4$, $7H_2O$ solution using diphenylamine indicator (Walkley and Black, 1934).

3.3.2.4 Organic matter

Organic matter was calculated by multiplying the value of organic carbon with Van Bemmelon factor 1.724.

3.3.2.5 Total nitrogen

Total nitrogen of soil was determined by micro Kjeldahl method where soil was digested with conc. H_2SO_4 and catalyst mixture K_2SO_4, $CuSO_4$, $5H_2O$: Selinium powder (100:10:1). Nitrogen in the digest was estimated by distillations with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with *0.01N* H_2SO_4 (Marr and Cresser, 1983).

3.3.2.6 Available nitrogen

The available nitrogen of the soil was determined by micro Kjeldahl's method after extracting the soil with *1N* potassium chloride. The distillation of extract was done with 40% NaOH and the distillates were collected on a 2% boric acid mixed indicator. The distillates were titrated against H_2SO4 (Marr and Cresser, 1983).

3.3.2.7 Available phosphorus

The available phosphorus of the soil was extracted by Troug's extraction reagent. The phosphorus in the extracts was estimated colorimetrically following the yellow color method using nitric acid at 430nm by spectrophotometer, model DR 5000 (HACH) (Jackson, 1958).

3.3.2.8 Exchangeable potassium

Soil in column was leached by *1N* NH_4OAc (pH-7.0) solution and exchangeable potassium in the leachate was determined by using flame photometer, model PFP 7 SL 9552 (JENWAY) (Pratt, 1965).

3.3.2.9 Available sulfur

Available sulfur was determined by extracting soil sample with 0.15% $CaCl_2$ solution (Bardsley and Lancaster, 1965). The sulfur content in the extract was determined turbidimetrically and the intensity of turbid was measured by using spectrophotometer at 420nm wavelength, model DR 5000 (HACH).

3.3.2.10 Available cupper, zinc, manganese, chromium, cadmium, lead and nickel

Cupper, zinc, manganese, chromium, cadmium, lead and nickel in soil, cow dung, rice bran, poultry litter and vermicompost were extracted by digestion with aquaregia (HCl :HNO_3=3:1). For this determination, 0.2g of sample was digested in 20 ml aqua-regia for approximately 3-4 hours using a sand bath as a heating source (approx. 150^0C). The sample and acid were placed in 100 ml glass beaker. After dissolution, samples were diluted up to a volume of 50ml, mixed and filtered prior to analysis (AOAC, 1990). Total copper, zinc, manganese, chromium, cadmium, lead and nickel contents of the soil samples were determined by a varian atomic absorption spectrometer (AAS), model 220.

3.4 Experimental

Four field experiments were conducted at the Research Farm of Charfasson Govt. College, Bhola during rabi seasons in 2015-2016 and 2016-2017 using four rates of each of cow dung (CD), rice bran (RB), vermicompost (VC) (0.0, 2.5, 5.0, 7.5t ha^{-1}), poultry litter (PL) (0.0, 1.5, 3.0, 4.5t ha^{-1}) and NPK (0.0, 50, 100, 150% RDF) alone and in combination on sunflower (*Helianthus annus* **L.** var. keroni-2). The doses were selected according to the Fertilizer Recommendation Guide 2012 of Bangladesh Agricultural Research Council (BARC).

Design	:	Completely Randomized Block Design (CRBD)
Replication	:	Three
Gross plot size	:	3.6m x 2.6m =9.36m^2
Net plot size	:	3m x 2m = 6m^2
Crop	:	Sunflower
Seed rate	:	6 kg ha^{-1}
Spacing	:	40 cm x 25 cm
Variety	:	BARI-2 (Keroni-2)
1st year		
Date of sowing	:	29. 12 .2015
2nd year		
Date of sowing	:	16 .12 .2016

3.4.1. Preparation of organic manures

3.4.1.1 Preparation of cow dung compost

For preparation of cow dung compost is to dig a specific size of trench near the cowshed. The cowshed had prepared for five cattle. A medium size of trench (6ft. L x 4ft. W x 3ft. D) was made for the preparation of cow dung from the cattle excreta (raw cow dung). It had added a drain from behind the cowshed to reservation trench. Through the drain, cattle urine and cowshed water pass to the trench. Moreover, a high basin around the trench was made to check the rainfall water. A shed also made on the trench by thick polyethylene paper. The polyethylene paper was tied tightly with the basin, but one portion of favorable side of polyethylene made loose for the pouring of cattle excreta. After 30 days interval, the raw cow dung stirred for well, complete and smooth decomposition. After fermentation, decomposed cow dung was taken a place away from the trench to a non shady place and was allowed to dry properly and grinded carefully. The well processed cow dung was then ready for application to the experimental fields.

3.4.1.2 Preparation of rice bran compost

Rice bran is the outermost layer of the paddy grain that is separated from the rice grain during milling process. Rice bran was collected from local market. Rice bran was filled into a plastic bag. It was placed in a high land on polyethylene paper where rain water did not stand. Sufficient amount of water was poured into the rice bran filled bag until the whole bran was wetted. When the whole bran was absorbed with water the top portion of the bag was tied tightly. After 15 days interval water was again poured on the rice bran bag if needed and stir it for well decomposition. The process continued for five months until complete decomposition occurred, when the rice bran decomposed fully, it was dried in a sunny place until retaining acceptable moisture content. Thereafter, the rice bran became ready for application to the experimental fields.

3.4.1.3 Preparation of poultry litter compost

The decomposed combination of poultry litter (bedding of poultry), poultry excreta and its wasted feed is called poultry manure. Sufficient amount of poultry litter in the local and urban poultry farm is available. It is piles of near the poultry farm. Poultry manure is collected from the near by poultry farm into an air passed plastic bag. It was placed in a high land on polyethylene paper where rains water did not stand. Sufficient amount of water was poured into the poultry litter filled bag until the whole poultry litter was wetted. When the whole poultry litter was absorbed with water on top portion of the bag bound tightly. After 15 days interval on the poultry litter in the bag water was again poured if needed and stir it for well decomposition occurred. When the poultry litter decomposed fully, it was dried in a sunny place until retaining a acceptable moisture content. Thereafter, the poultry litter became ready as poultry manure for application to experimental field.

3.4.1.4 Preparation of vermicompost

Vermicompost are finely divided mature peat like materials which are produced by a non-thermophyllic process involving interactions between earth warms and microorganisms (Edwards and Burrows, 1988) leading to bio-oxidation and stabilization of cow dung (Aira *et al*., 2000). Cow dung (CD) was used as raw material to prepare vermicompost. The procedure for preparation of vermicompost was followed as anaerobic conditions. The size of beds 4ft

W x 2.5ft D x 4ft L prepared with the help of bricks under a shed open from all sides for preparing of vermicomposting of cow dung. Fresh cow dung was put into the bed of the pit about 1ft D. The earth warm (*Eisenia foedita*) about 1000 per 100kg material, were introduced into the bed. They were allowed to acts for 40 days, which converted the whole material into a well decomposed fine product named vermicompost. After this certain period of incubation, vermicompost was ready for application in the experimental field.

3.4.2 Analysis of cow dung, rice bran, poultry litter and vermicompost

Organic manures were analyzed for pH, per cent of organic carbon, N, P, K, S and heavy metals.

Table 3.5 Some properties of cow dung, rice bran, poultry litter and vermicompost

Parameters	Cow dung	Rice bran	Poultry litter	Vermicompost
Moisture content (%)	15.00	17.00	14.00	18.00
pH	7.30	7.60	7.75	7.30
EC (dSm^{-1})	0.20	0.25	1.25	0.17
OC (%)	7.50	6.20	7.80	6.50
C:N	10.71	8.16	6.05	6.02
N (%)	0.70	0.76	1.29	1.08
P (%)	0.14	0.22	0.55	0.30
K (%)	0.36	0.32	0.90	0.80
S (%)	0.20	0.60	0.27	0.21
Cu ($mg\ kg^{-1}$)	77.20	44.10	90.00	62.90
Zn ($mg\ kg^{-1}$)	33.00	6.00	259.00	150.00
Cd ($mg\ kg^{-1}$)	1.40	1.00	ND	ND
Cr ($mg\ kg^{-1}$)	ND	ND	ND	ND
Pb ($mg\ kg^{-1}$)	5.00	2.00	ND	9.00
Ni ($mg\ kg^{-1}$)	8.10	3.20	4.70	7.20

3.5 Crop husbandry

3.5.1 Experimental design

The experiment was laid out in a Completely Randomized Block Design (CRBD). Four experiments were conducted on the basis of organic sources (cow dung, rice bran, poultry litter and vermicompost) with the combination of NPK inorganic fertilizer. Each experiment had sixteen treatments with three replications. For the reason, total plot of each experiment were 48. Each net plot was 3 m length and 2 m width and gross plot was 3.6 m length and 2.6 m width.

The space between the plots and blocks were 1 m and between two experiments were 1.5 meters. There was a deep drain around the blocks and plots. The design informations were shown in the section 3.4, in format.

3.5.2 Land preparation

At the beginning of the experiments, land was prepared finely with repeat ploughed and cross plough for four times by spade followed by laddering. After ploughed the clods and lumps were broken with the help of wooden hammer to make the soil in good tilth. Weed and residues of previous crops were cleaned properly. Drainage channel was made around the field to remove the excess water from the plots.

3.5.3 Fertilizer application

Inorganic fertilizers for sunflower were selected on the basis of Fertilizer Recommendation Guide of Bangladesh Agriculture Research Council (BARC, 2012). The above mention FRG (2012) of BARC was also followed for selecting the dose of manures (Cow dung, rice bran, poultry litter and vermicompost). Treatment combination of recommended fertilizers for sunflower experiment from organic sources and inorganic fertilizers were mansion aforesaid experimental. The full dose organic sources were applied at the primary stage of land preparation and P as Triple Super Phosphate (T.S.P), K as Muriate of Potash (MoP) and half dose of N from urea were applied at the final land preparation before sowing of seed. The remaining urea was applied in two equal splits as top dressing at 25 and 45 days after emergence. Weeding, spading, thinning, vacancy supply, fencing, netting, and spraying pesticide and herbicide were done as and when necessary.

3.5.4 Sowing of seeds

The distance between rows to row was 40 cm and 25 cm from seed to seed at the depth of 4 cm. After sowing, seeds were covered with soil by hand. Each point was sown 2 to 3 seeds. The rate of seed was 6 kg ha^{-1}. The seeds were sown during the last week of December 2015 and 2016.

3.5.5 Germination of seeds

Healthy and good quality of seeds were collected from BADC seed dialer of Barisal division and sown in experimental plots. Germination of seeds started from 4 days of sowing. The percentage of germination was satisfactory every year. All the seeds were germinated within 7 days.

3.5.6 Intercultural practices

Necessary intercultural operations were duly employed during the field experiment.

3.5.6.1 Insects and diseases management

Pesticide, Ripcord 10 EC (phyrethroade) and fungicide, sulcox (copper oxi-cloride) were used for killing insects and diseases. During the bourgeoning period, sunflower leaves were affected by caterpillars, it further affected during the flowering stage, seed formation stage. Plenam was applied to control caterpillars.

3.5.6.2 Weeding, thinning and vacancy supplying

Weeding was done at the stage of 15, 30 and 45 days after sowing of seed. Thinning and vacancy filling was done of 15 days after sowing.

3.6 Biometric observations

Randomly ten plants from each net plot was selected and labeled for recording growth parameters at different growth stages *viz*., 30, 60 and 90 days respectively after sowing and biometric observations such as height, number of leaves, leaf area and leaf area index were recorded in the following way.

3.6.1 Plant height (cm)

Heights were measured from the base of the plant at ground level to the tip of the leaf.

3.6.2 Number of leaves plant^{-1}

Leaves were counted with the help of a talley counter.

3.6.3 Leaf area (cm^2)

Length and width were measured and multiplying them.

3.6.4 Leaf area index

The leaf area index was calculated using the following formula given by Watson (1952).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area plant}^{-1}}{\text{Land area}}$$

3.7 Harvesting

Sunflower plants were harvested as root, stem, leaf, petiole, inflorescence and seed. Leaves and stems were become yellowish and seeds were deep black in color and matured. It was harvested 1 sq. m of each replication randomly on the middle of the plots. Roots were washed by tap water and finally washed with distilled water and rapped with tissue paper. Fresh weights of roots, stems, leaves, petioles, inflorescences and seeds were taken with the help of mettler toledo balance. These samples were kept into paper packet and dried in sunshine until sample weights were constant. Then dry weights were taken with the help of mettler toledo balance.

3.7.1 Head diameter (cm)

Fresh head diameters (cm^2) were measured.

3.7.2 Threshing seed

Threshing of seeds was done mechanically. Seeds were clean and dried, and weight was recorded accordingly.

3.8 Yield components

3.8.1 Number of seeds (plant^{-1})

The selected sample of each treatments and replications were counted in a talley counter.

3.8.2 Seed yields (g plant^{-1})

The dried heads from each plot were harvested, cleaned and the weights of the seeds were measured (g plant^{-1}).

3.8.3 100 seeds weight (g)

Hundred seeds were counted randomly from each plot and weight (g) was taken.

3.9 Digestion of plant sample for N concentration

Plant samples i.e. roots, stems, leaves, petioles, inflorescences and seeds were digested with sulfuric acid and digestion mixture (catalyst) and nitrogen was determined by alkali distillation of the micro Kjeldahl digestion method (Marr and Cresser, 1983).

3.10 Digestion of plant samples with nitric perchloric acid mixture for PKS contents

0.5gm of sample was taken into a dry clean 100 ml of micro Kjeldahl flask, 10 ml of di-acid mixture (HNO3, HClO4 in the ratio of 2:1) was added and kept for few minutes. Then the flask was heated at a temperature rising slowly to 200^{0}C. The content of the flask was boiled until it became clear and colorless.

3.10.1 The digest was used for determining phosphorus, potassium and sulfur

3.10.1.1 Phosphorus

Phosphorus in plant sample was determined by the vanadomolybdophosphoric yellow color method (Jackson, 1958) with the help of a spectrophotometer model DR 5000 (HACH).

3.10.1.2 Potassium

Potassium was determined by using flame photometer model PFP 7 SL 9552 (JENWAY) (Pratt, 1965).

3.10.1.3 Sulfur

Sulfur content in the digest was determined by turbidimetric method as described by Bardsley and Lancaster (1965) using spectrophotometer model DR 5000 (HACH).

3.11 Oil of seed and oil yield

Estimation of oil content (%) in the seed sample was done at the Centre for Advanced Research in Science (CARS), the University of Dhaka by Soxhlet Fat Extraction method evolved by (AOAC, 1990).

3.12 Seed protein

Seed protein content was calculated by multiplying the N content of seed with a factor of 6.25

Seed protein content = % of seed N content x 6.25

3.13 Uptake of nutrients by root, stem, leaf, petiole, inflorescence and seed of sunflower plant

The uptake of nutrients by different parts of sunflower plant was worked out by multiplying the nutrient concentration and dry matter yield of the plant parts as given in the following formula:

$$\text{Nutrient uptake (g plant part}^{-1}\text{)} = \frac{\text{\% Nutrient concentration x Biomass yield (g plant part}^{-1}\text{)}}{100}$$

3.14 Economic analysis

The cost of inputs that were prevailing at the time of their use was considered for working out the economics of various treatment combinations. A net return ha^{-1} was calculated by deducting the cost of cultivation from gross income ha^{-1} and benefit cost ratio was worked as fallows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return ha}^{-1}}{\text{Cost of cultivation ha}^{-1}}$$

3.15 Statistical analysis

Statistical analysis was carried out by SPSS programme. Means was compared by least significant difference (LSD) test.

CHAPTER 4

Impacts of NPK Fertilizers and Cow Dung on the Growth, Yield and Nutrient Content of Sunflower (*Helianthus annus* L.)

4.1 Introduction

Cow dung has always been considered as a valuable input to the soil for crop production. In a broad sense, manure management relates to the appropriate use of animal manure according to each farm capabilities and goals while enhancing soil quality, crop nutrition. The effect of cow dung on soil is that it increases the geotechnical properties like bulk density, dry density, increased water holding capacity, porosity, infiltration and can also improve the soil structure i.e. granular and crumb.

Manure management is defined as a decision-making process aiming to combines profitable agricultural production with minimal nutrient losses from manure, for the present and in the future. Cow dung helps to increase the soil buffering capacity, thus helping to regulate soil acidity. Degraded soil may be alkali, acidic and saline in nature. Application of cow dung increase soil organic matter which regulate the soil reaction (P^H) and thus create favorable conditions for availability of maximum nutrients to plants. Cow dung increases soil organic matter. Soil organic matter is an important component in terrestrial ecosystems. It harbors a rich microbial diversity, containing different species of bacteria (*Bacillus, Corynebacterium* and *Lactobacillus*), Protozoa and Yeast (*Saecharomyces* and *Candia*) (Kartikey *et al.*, 2016). In composting, microorganisms decompose organic substrate aerobically into $C0_2$, water, minerals and stabilized organic matter (Vakili *et al.*, 2015). Soil organic matter plays a key role in mitigation climate change by capturing atmospheric carbon dioxide, an important radioactively active gas emitted mainly by anthropogenic activities (Alexander *et al.*, 2015) and prevent soil degradation and for sustainable agriculture.

Excessive chemical fertilizers application of sunflower plants i.e. N fertilizer not only generates the environmental risk, it may also affect the grain quality, decreasing its oil content and reduce yield through an increase of plant lodging (Scheiner *et al.*, 2002).

The combined use of manures and NPK fertilizers increased crop yield and improve soil health by maintaining soil physical, chemical, biological properties and environmental hazard.

Therefore, the present experiment was carried out to evaluate the influenced of NPK fertilizers and cow dung on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L**.) at the research farm of Charfasson Govt. College, Bhola, during 2015-2016 in rabi season.

4.2 Materials and methods

4.2.1 Location, description and climatic condition

Geographic location, description and climatic condition of the experimental site are described in the sections 3.1 and 3.2; and Tables 3.1 and 3.2, respectively, in Chapter 3.

4.2.2 Collection of soil samples and analysis

4.2.2.1 Physical properties of soil

Soil sample collection and physical properties of soil, i.e. particle size, textural class, bulk density, particle density, maximum water retentive capacity are described in the sections 3.3, 3.3.1, 3.3.1.1, 3.3.1.2, 3.3.1.3, 3.3.1.4 and 3.3.1.5, respectively, and Table 3.4 in Chapter 3.

4.2.2.2 Chemical properties of soil

Soil chemical properties i.e. P^H, EC, OC, OM, total nitrogen, available nitrogen, available phosphorus, exchangeable potassium, available sulfur and heavy metal are described in the sections 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.2.7, 3.3.2.8, 3.3.2.9 and 3.3.2.10, respectively, and Table 3.4 in Chapter 3.

4.2.3 Experimental

Experimental description, preparation of cow dung compost, and its physical and chemical analysis are described in the sections 3.4, 3.4.1, 3.4.1.1 and 3.4.2, respectively, and Table 3.5 in Chapter 3.

4.2.3.1 Treatments of NPK fertilizers and cow dung

CD_1 : Control -(CD & NPK)
CD_2 : 2.5 t CD ha^{-1} (50% RDF)
CD_3 : 5t CD ha^{-1} (100% RDF)
CD_4 : 7.5t CD ha^{-1} (150% RDF)
CD_5 : $N_{40}P_{30}K_{50}$ kg ha^{-1} (50% RDF)
CD_6 : $N_{80}P_{60}K_{100}$ kg ha^{-1} (100% RDF)
CD_7 : $N_{120}P_{90}K_{150}$ kg ha^{-1} (150% RDF)
CD_8 : 2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}
CD_9 : 2.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}
CD_{10} : 2.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}
CD_{11} : 5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}
CD_{12} : 5t CD ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}
CD_{13} : 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}
CD_{14} : 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}
CD_{15} : 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}
CD_{16} : 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1}

4.2.4 Crop husbandry

Design, land preparation, fertilizers application, sowing of seed, germination of seed, intercultural practices i.e. insects and diseases management, weeding, spading, thinning and vacancy supplying are described in the sections 3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.6.1 and 3.5.6.2, respectively, in Chapter 3.

4.2.5 Biometric observations

Biometric observations i.e. plant height (cm), number of leaves $plant^{-1}$, leaf area (cm^2), leaf area index (LAI), are described in the sections 3.6, 3.6.1, 3.6.2, 3.6.3 and 3.6.4, respectively, in Chapter 3.

4.2.6 Harvesting and yield components

Harvesting, head diameter (cm), threshing seed, yield components *viz.* number of seeds $plant^{-1}$, seed yield (g $plant^{-1}$), 100 seed weight (g) are described in the sections 3.7, 3.7.1, 3.7.2, 3.8, 3.8.1, 3.8.2 and 3.8.3, respectively, in Chapter 3.

4.2.7 Plant sample analysis

Digestion of plant samples for nitrogen concentration, digestion of plant samples (root, stem, leaf, petiole, inflorescence and seed) with conc. nitric perchloric acid mixture, determination of phosphorus, potassium, sulfur concentration, oil of seed and oil yield (g $plant^{-1}$), seed protein are described in the sections 3.9, 3.10, 3.10.1, 3.10.1.1, 3.10.1.2, 3.10.1.3, 3.11 and 3.12, respectively, in Chapter 3.

4.2.8 Uptake of nutrient

Uptake of nutrients by different parts of sunflower plant is described in the section 3.13 in chapter 3.

4.2.9 Economic analysis

Economic analysis is described in the sections 3.14 in Chapter 3.

4.2.10 Statistical analysis

Statistical analysis is described in the sections 3.15 in Chapter 3.

4.3 Results and discussion

Effects of NPK fertilizers and cow dung on the growth, yield, nutrient concentration and uptake, quality of seed and benefit: cost ratio of sunflower have been discussed in this portion.

Cow dung; 0.0, 2.5, 5.0, 7.5t ha^{-1} and NPK fertilizers; 0.0, 50, 100, 150% of recommended doses; alone and in combinations were applied.

4.3.1 Effects of NPK fertilizers and cow dung on growth parameters of sunflower plant

Agronomic parameters *viz.* height (cm), leaf number ($plant^{-1}$), leaf area (cm^2) and leaf area index of sunflower plant as influenced by cow dung and fertilizers were measured at 30, 60 and 90 days after sowing (Tables 4.1-4.2). Both parameters were found statistically significant ($P< 0.5$) over the control and treatments to treatments were observed statistically identical in most of the cases.

4.3.1.1 Height (cm) and number of leaf (plant^{-1})

Results showed that height (cm) and number of leaf were significantly ($P< 0.5$) increased over the control (Table 4.1). Results further revealed that height and leaf number gradually increased with growth period irrespective of the treatments. Moreover, the parameters also increased with the increase rates of cow dung and fertilizers in most of the cases.

However, the variations among the treatments, in most of the treatments were found to be statistically not significant. Maximum height of plant and number of leaf plant^{-1} at maturity were 208.4cm in treatment (7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}) and 41.2 in treatment (2.5t CD+ $N_{120}P_{90}K_{150}$kg ha^{-1}) respectively. Minimum values were recorded in the control in all the cases of growth parameters (Table 4.1).

Between cow dung and fertilizers, fertilizers alone showed better results than cow dung in case of height and number of leaf. Generally, highest doses of both the cow dung and fertilizers together produced comparatively higher results.

4.3.1.2 Leaf area (cm^2) and leaf area index

Results showed that leaf area (cm^2) and leaf area index were significantly ($P< 0.5$) increased over the control (Table 4.2). Results further revealed that leaf area (cm^2) and leaf area index gradually increased with growth period irrespective of the treatments. Moreover, the parameters also increased with the increase rates of cow dung and NPK fertilizers in most of the cases.

However, the variations among the treatments, in most of the treatments were found to be statistically not significant. Maximum leaf area and leaf area index at maturity were 410.5cm^2 in treatment (7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}) and 12.75 in treatment (7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}) respectively. Minimum values were recorded in the control in all the cases of growth parameters (Table 4.2).

Table 4.1 Effects of NPK fertilizers and cow dung on height (cm) and number of leaf (plant^{-1})

Treatments	Days after sowing					
	Height (cm)			Number of leaf (plant^{-1})		
	30	60	90	30	60	90
CD_1: Control.	22.0	91.7	97.2	9.3	18.0	24.2
CD_2: 2.5t CD ha^{-1} (50 % RDF)	26.7	118.0	125.2	10.0	23.7	30.0
CD_3: 5t CD ha^{-1} (100 % RDF)	29.5	110.0	117.6	11.3	22.7	32.5
CD_4: 7.5t CD ha^{-1} (150 % RDF)	36.8	130.3	144.4	12.7	27.0	36.5
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	28.7	143.7	155.6	12.0	23.7	33.7
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	47.7	167.0	180.1	14.0	33.3	37.2
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	38.0	170.3	190.5	14.0	29.7	39.0
CD_8: 2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	40.7	158.3	181.0	13.3	28.0	36.6
CD_9: 2.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1}	38.7	184.0	192.2	12.0	30.3	39.5
CD_{10}: 2.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	48.0	188.0	198.6	15.3	33.7	41.2
CD_{11}: 5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	39.0	161.7	177.5	12.0	22.7	34.3
CD_{12}: 5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1}	40.0	177.3	193.7	14.3	24.7	35.7
CD_{13}: 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}	48.7	179.3	199.5	12.7	25.7	33.2
CD_{14}: 7.5t CD ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1}	42.3	179.7	196.4	14.3	24.7	36.4
CD_{15}: 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1}	44.0	182.0	202.6	14.7	24.3	37.6
CD_{16}: 7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}	46.8	195.0	208.4	15.3	27.0	39.5
LSD at 5	7.25	20.80	20.79	1.64	5.4	5.62

RDF= Recommended dose of fertilizer CD=Cow dung

Table 4.2 Effects of NPK fertilizers and cow dung on leaf area (cm^2) and leaf area index

Treatments	Days after sowing					
	Leaf area (cm^2)			Leaf area index		
	30	60	90	30	60	90
CD_1: Control	49.8	85.7	82.3	0.47	1.52	1.30
CD_2: 2.5t CD ha^{-1} (50 % RDF)	72.9	146.6	140.6	0.73	3.43	2.32
CD_3: 5t CD ha^{-1} (100 % RDF)	91.4	151.8	155.3	1.04	3.45	3.95
CD_4: 7.5t CD ha^{-1} (150 % RDF)	89.5	135.4	149.5	1.14	3.73	4.65
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	86.3	221.7	237.3	1.05	5.22	6.20
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	136.9	321.3	320.4	1.92	9.57	9.22
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150%RDF)	116.0	256.3	290.5	1.64	6.77	8.26
CD_8: 2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	127.7	262.5	270.5	1.63	7.50	7.30
CD_9: 2.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	126.2	311.3	320.2	1.51	9.42	8.75
CD_{10}:2.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	179.6	389.0	360.3	2.75	13.18	12.16
CD_{11}: 5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	104.7	182.7	247.0	1.26	4.92	7.50
CD_{12}: 5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1}	139.3	235.5	325.2	2.00	6.29	8.10
CD_{13}: 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	168.4	328.0	381.2	2.13	8.40	9.80
CD_{14}: 7.5t CD ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1}	114.3	241.7	264.0	1.64	5.98	7.80
CD_{15}:7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	177.1	267.3	359.4	2.51	6.50	9.62
CD_{16}:7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kgha^{-1}	161.9	425.7	410.5	2.47	11.54	12.75
LSD at 5 %	37.56	89.39	8.75	0.57	3.07	5.62

RDF= Recommended dose of fertilizer. CD=Cow dung.

4.3.2 Effects of NPK fertilizers and cow dung on dry matter and seed yield parameters of sunflower

Effects of cow dung and NPK fertilizers on dry matter and seed yield parameters of sunflower have been examined and the results thus obtained are presented in Table 4.3.

Cow dung; 0.0, 2.5, 5.0, 7.5t ha^{-1} and fertilizers NPK: 0.0, 50, 100, 150 % of recommended doses; alone or in combinations applied on sunflower showed a positive effect on the growth and yield of sunflower. Most of the treatments showed significantly ($P< 0.05$) effect on the dry matter and seed yield parameters of sunflower plant over the control.

Results also showed that all the treatments caused an increase in highest weight of root, stem, leaf, petiole, inflorescence, dry matter and seed yields together with weight of 100 seeds of sunflower plant (Table 4.3). Treatments showed that combinations of organic manures and fertilizers (NPK) produced better results than their individual effects. Among the treatments cow dung applied at the rate of 7.5t ha^{-1} with RDF ($N_{120}P_{90}K_{150}$kg ha^{-1}) produced the highest result in most of the cases.

4.3.2.1 Dry weights of root and stem (g $plant^{-1}$)

Cow dung alone produced significantly ($P< 0.05$) better yield of root (4.67g $plant^{-1}$) at the highest rate i.e. at 7.5t ha^{-1} over the control (Table 4.3). The intermediate doses showed no significant change in weight of root. Weight of stem, however, showed no significant change due to addition of cow dung over the control. Similar non-significant effects were observed in root and stem weights of sunflower plant when NPK fertilizers were applied except the treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}, which showed significant increase in stem weight of this crop over the control. Application of NPK fertilizer showed comparatively better stem weight than lower doses of NPK and even cow dung when applied alone.

The overall highest yields of root (12.83g) and stem (60.67g) were recorded at treatments 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively (Table 4.3). The higher dose of cow dung and NPK, in rest of the treatments, showed no significant improvement in root and stem yield. The variations among the treatments were also found to be not significant in both the cases of root and stem dry weights.

Table 4.3 Effects of NPK fertilizers and cow dung on dry matter and seed yield parameters of sunflower

Treatments	Root (g $plant^{-1}$)	Stem (g $plant^{-1}$)	Leaf (g $plant^{-1}$)	Petiole (g $plant^{-1}$)	Inflores-cence (g $plant^{-1}$)	Total dry matter yield (g $plant^{-1}$)	Total dry Matter yield (t ha^{-1})	Diameter Of inflo-rescence (cm)	Seed wt. (g $plant^{-1}$)	Number of seed (g $plant^{-1}$)	Wt. of 100 seed (g)
CD_1: Control.	0.83	10.00	6.67	1.50	6.00	25.00	1.3	24.67	7.8	129.3	6.0
CD_2: 2.5t CD ha^{-1} (50 % RDF)	2.00	11.33	8.00	2.17	10.00	33.50	1.7	29.67	13.3	250.0	5.3
CD_3: 5t CD ha^{-1} (100 % RDF)	2.00	15.33	8.67	2.67	10.67	39.34	2.0	32.00	15.3	314.0	4.9
CD_4: 7.5t CD ha^{-1} (150 % RDF)	4.67	19.33	9.33	3.00	14.67	51.00	2.6	34.33	18.8	291.0	6.4
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	5.67	22.67	11.33	3.17	14.00	56.84	3.0	40.33	24.0	439.0	5.5
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	6.00	20.67	11.67	5.83	12.00	56.17	3.9	48.67	37.3	466	7.9
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	6.67	37.33	16.00	5.67	15.33	81.00	4.2	47.67	34.0	570	6.1
CD_8: 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	7.00	53.33	18.00	5.33	14.67	98.33	5.1	48.33	40.7	508.3	8.0
CD_9: 2.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	6.33	38.00	15.33	6.00	14.67	80.33	4.2	46.67	41.7	521.7	7.9
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	8.67	32.67	13.33	6.83	15.33	76.83	4.0	47.00	35.7	647.0	5.5
CD_{11}: 5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	9.33	44.00	17.33	6.50	16.67	93.83	4.9	44.67	41.1	483.3	8.5
CD_{12}: 5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	8.00	37.67	18.67	7.50	17.00	88.84	4.6	45.67	52.7	592.0	8.7
CD_{13}: 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	10.33	40.00	19.33	8.00	17.33	94.99	4.9	52.67	57.3	735.7	7.7
CD_{14}: 7.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	11.33	46.67	25.33	9.33	18.00	110.66	5.7	45.67	60.6	631.7	9.6
CD_{15}: 7.5t CD+ $N_{80}P_{60}K_{100}$kg ha^{-1}	12.83	42.00	16.67	9.67	18.67	99.84	5.2	51.00	64.7	658.3	9.8
CD_{16}: 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	10.67	60.67	20.67	10.00	19.33	121.34	6.3	52.33	54.0	616.7	8.7
LSD at 5%.	3.50	22.21	7.41	4.17	4.83	9.46	0.53	11.83	16.65	187.4	1.31

RDF=Recommended dose of fertilizer CD = Cow dung

4.3.2.2 Dry weight of leaf (g plant^{-1})

Dry weight of leaf of sunflower plant did not improve due to addition of cow dung and NPK when applied alone significantly ($P< 0.05$) over the control except the treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}, which showed significant increase over the control (Table 4.3). Combination of cow dung and NPK fertilizers in higher doses produced significant increase in weight of leaf of the sunflower crop over the control. However, the variations among the treatments were found to be not significant in most of the treatments. The highest leaf weight (25.33g) was recorded in the treatment, 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kgha^{-1} (Table 4.3).

4.3.2.3 Dry weight of petiole (g plant^{-1})

Dry weight petiole of leaf varied from control to highest combination of treatment 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.3). Application of cow dung and fertilizer in different combinations when applied alone showed no significant increase in dry weight of petiole of sunflower except the treatments, $N_{80}P_{60}K_{100}$kg ha^{-1} and $N_{120}P_{90}K_{150}$kg ha^{-1} where the weight showed significantly ($P< 0.05$) higher yields than the control.

Combined effect of cow dung and fertilizer in various combinations produced significantly ($P< 0.05$) higher yield of petiole plant^{-1} over the control in all the cases except the treatments where lowest dose of NPK and cow dung were applied i.e. in the treatment, 2.5t CD ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1}. Maximum yield of petiole (10.0g plant^{-1}) was found in the treatment where the highest level of both cow dung and fertilizers were applied together (Table 4.3).

4.3.2.4 Dry weight of inflorescence (g plant^{-1})

Dry weight of inflorescence plant^{-1} of sunflower increased significantly ($P< 0.05$) over the control due to application of cow dung and fertilizers in all the combinations (Table 4.3).

Results showed that fertilizers produced comparatively better result than cow dung when applied alone except the treatment 7.5t CD ha^{-1}, which showed higher result but statistically identical to the treatment, $N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.3).

All the treatments of cow dung and fertilizers together caused better effect than their individual applications and were statistically significant over the control. However, when the treatments were compared among themselves, they were found to be statically identical. The highest weight of inflorescence plant^{-1} (19.33g) was observed in treatment where the highest doses of cow dung and fertilizers were applied (Table 4.3).

4.3.2.5 Diameter of inflorescences (cm)

The diameter of inflorescences of sunflower followed the all most same trend as in case of dry weight of inflorescences (Table 4.3).

Comparison between the individual application of rates of cow dung and fertilizers showed identical results but in case of fertilizers, statistically significant ($P< 0.5$) results were recorded over the control. This means that fertilizers played better in this respect but the variation in rates were statistically not significant. Combined applications of cow dung and fertilizers produced higher results than cow dung and fertilizers when applied alone. The diameter of inflorescence of sunflower increased with the increase rate of cow dung and fertilizers and the maximum diameter (52.67cm) was found in the treatment, 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}. It is clear that irrespective of the rates, diameter of inflorescence of sunflower remained statistically identical (Table 4.3).

4.3.2.6 Total dry matter yield (g plant^{-1}) and (t ha^{-1})

Total dry matter yield of sunflower plant (g plant^{-1} and t ha^{-1}) was measured at maturity (Table 4.3).

Yield of dry matter plant^{-1} and ha^{-1} increased with increasing rates of cow dung and fertilizers. Between the effects of cow dung and fertilizers when applied alone, fertilizers performed better in this respect. Highest productions of dry matter in both the measures were recorded in the same treatment i.e. in treatment where the highest rates of both cow dung and fertilizers were applied together and the values were 121.34g plant^{-1} and 6.3t ha^{-1} respectively (Table 4.3). Trend in changes in dry matter production in both the agronomic parameters were almost same which is quite obvious.

4.3.2.7 Number of seed (plant^{-1}) and weight of seed (g plant^{-1})

Weight of seeds plant^{-1} and number of seeds plant^{-1} varied significantly ($P< 0.05$) due to applications of cow dung and fertilizers (Table 4.3).

Weight of seed plant^{-1} increased with increasing rates of cow dung and fertilizers applied either alone or in combination. The effects of treatments were found to be statistically significant ($P < 0.05$) over the control in most of the treatments. Higher rates of fertilizers applied alone showed significant increase in seed yield plant^{-1} over the control. However, the variations among the seed yields plant^{-1} and weight of seeds plant^{-1} due to treatments were found to be statistically identical in most of the cases, no matter weather cow dung and fertilizer were applied alone or in combination.

Highest yield of seed plant^{-1} (64.7g) was increased in 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} treatment. The highest number of seeds plant^{-1} (735.7) was recorded in 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatment (Table 4.3).

4.3.2.8 Weight of 100 seed grains (g)

Treatments of cow dung and fertilizers in different combinations on sunflower showed that most of the combined treatments produced significantly ($P < 0.05$) increase in weight of 100 grains over the control (Table 4.3).

The results further showed that weight of 100 grains generally increased with the increasing rates of cow dung and fertilizers. However, the variations among the treatments in most of the cases were not significant. The highest weight of 100 grains (9.8g) was found in 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} treatment (Table 4.3).

4.3.3 Nutrient concentration and uptake of different organs of sunflower plant

4.3.3.1 Concentration and uptake of NPKS in stem

Nitrogen, phosphorus, potassium and sulfur concentrations and uptakes in stem of sunflower plants were significantly ($P < 0.05$) increased over the control (Table 4.4).

Values of concentration and uptake of NPKS increased with rates of NPK fertilizers and cow dung.

4.3.3.1.1 Concentration and uptake of nitrogen

The change in concentration of nitrogen between treatments was statistically identical in most of the treatments. The range of concentration and uptake of nitrogen varied from 0.29 to 1.33% and 29.0 to 532.0 mg plant^{-1} stem respectively (Table 4.4).

Table 4.4 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in stem

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
CD_1: Control	0.29	29.0	0.16	16.0	0.55	55.0	0.04	4.0
CD_2: 2.5t CD ha^{-1} (50 % RDF)	0.32	36.3	0.20	22.7	0.90	102.0	0.10	11.3
CD_3: 5t CD ha^{-1} (100 % RDF)	0.34	52.1	0.21	32.2	0.95	145.6	0.12	18.4
CD_4: 7.5t CD ha^{-1} (150 % RDF)	0.53	102.4	0.24	46.4	1.25	241.6	0.14	27.1
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.30	68.0	0.24	54.4	1.40	317.4	0.06	13.6
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.31	64.1	0.25	51.7	1.50	310.1	0.05	10.3
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.36	134.4	0.25	93.3	1.60	597.3	0.09	33.6
CD_8: 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.31	165.3	0.27	144.0	1.64	874.6	0.12	64.0
CD_9: 2.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	0.32	121.6	0.26	98.8	1.57	596.6	0.14	53.2
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.41	133.9	0.30	98.0	1.67	545.6	0.17	55.5
CD_{11}: :5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.37	162.8	0.26	114.4	1.42	624.8	0.17	74.8
CD_{12}: 5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	0.45	169.5	0.24	90.4	1.78	670.5	0.14	52.7
CD_{13}: 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.33	532.0	0.33	132.0	1.85	740.0	0.15	60.0
CD_{14}- 7.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.49	228.7	0.21	98.0	1.70	793.4	0.16	74.7
CD_{15}: 7.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	0.52	218.4	0.20	84.0	1.80	756.0	0.19	79.8
CD_{16}: 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.45	273.0	0.31	188.1	1.64	995.0	0.12	72.8
LSD at 5%	0.074	3.1	0.074	3.39	0.27	22.86	0.053	4.74

RDF=Recommended Doses of Fertilizer CD= Cow dung Conc. = Concentration

The highest values of both concentration and uptake of nitrogen were recorded in 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} treatment. The values of uptake followed the pattern of dry matter yield of stem (Tables 4.3, 4.4).

4.3.3.1.2 Concentration and uptake of phosphorus

Phosphorus concentration and uptake of sunflower stem followed a very similar pattern of nitrogen concentration (Table 4.4). Content and uptake of phosphorus showed a significant positive change with rates of both fertilizers and cow dung in all combinations. Concentrations of phosphorus were showed identical in most of the treatments. The highest values of phosphorus concentration and uptake were 0.33% and 188.1 mg plant^{-1} stem respectively.

The values were observed in the treatments, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively. The change in uptake of phosphorus followed the trend of dry matter yield of root (Tables 4.3, 4.4).

4.3.3.1.3 Concentration and uptake of potassium

Application of NPK fertilizers and cow dung caused significant increase in concentration and uptake of potassium in stem of sunflower when applied in different combinations (Table 4.4). Results showed that both concentration and uptake of potassium in sunflower stem increased with the increase in doses of NPK fertilizers and cow dung. However, the variations in concentration of potassium between the treatments were not statistically significant ($P< 0.05$). Similar trend was also observed in uptake of potassium in stem. Maximum concentration (1.85%) and uptake (995.0mg plant^{-1} stem) of phosphorus were recorded in 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1}+ $N_{120}P_{90}$ K_{150}kg ha^{-1} treatments respectively (Table 4.4).

The range of concentration and uptake of potassium varied from 0.55 to 1.85% and 55.0 to 995.0mg plant^{-1} stem respectively. The uptake of potassium also followed the pattern of dry matter yield of stem (Tables 4.3, 4.4).

4.3.3.1.4 Concentration and uptake of sulfur

Concentration and uptake of sulfur in stem of sunflower varied significantly ($P< 0.05$) due to treatments of NPK fertilizers and cow dung over the control (Table 4.4). Concentration and uptake of sulfur in stem increased with increasing rates of both NPK fertilizers and cow dung. The variations in concentration of sulfur between the treatments were found to be not significant in most of the cases. The uptake pattern of sulfur in stem followed the same treated of dry matter yield of sunflower (Table 4.4). The range of sulfur concentration and uptake varied from 0.04 to 0.19% and 4.0 to 79.8 mg plant^{-1} stem respectively. Both the highest values of concentration and uptake of sulfur were recorded in the treatment, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}.

4.3.3.2 Concentration and uptake of NPKS in root

Effects of cow dung and NPK on concentration and uptake of nitrogen, phosphorus, potassium and sulfur in root of sunflower have been measured (Table 4.5). Treatments of both NPK fertilizers and cow dung in different combinations significantly ($P< 0.05$) increased the concentrations and uptakes of nitrogen, phosphorus, potassium and sulfur with increasing rates of fertilizers and cow dung.

4.3.3.2.1 Concentration and uptake of nitrogen

Results showed that variations between treatments to treatments, nitrogen in most of the cases were not significant (Table 4.5).

Moreover, in a few treatments *viz.* 5t CD ha^{-1}, 7.5t CD ha^{-1}, 2.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha $^{-1}$ and 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} were found to be statistically significantly ($P< 0.05$) higher nitrogen concentration than other treatments.

The highest concentration (1.08%) and uptake (111.7mg plant^{-1} root) were recorded in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Concentration and uptake of nitrogen ranged from 0.35 to 1.08% and 2.9 to 111.7 mg plant^{-1} root respectively (Table 4.5).

4.3.3.2.2 Concentration and uptake of phosphorus

Variation in phosphorus concentration of root of sunflower also revealed very similar pattern like nitrogen due to treatments of NPK fertilizers and cow dung (Table 4.5).

Table 4.5 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in root

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
CD_1: Control	0.35	2.9	0.17	1.41	0.66	5.48	0.02	0.18
CD_2: 2.5t CD ha^{-1} (50 % RDF)	0.42	8.4	0.19	3.80	1.21	24.2	0.12	2.46
CD_3: 5t CD ha^{-1} (100 % RDF)	0.53	10.6	0.22	4.40	1.45	29.0	0.13	2.58
CD_4: 7.5t CD ha^{-1} (150 % RDF)	0.77	36.0	0.24	11.21	1.59	74.3	0.12	5.46
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.52	29.5	0.24	13.61	1.15	65.2	0.05	2.61
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.54	32.4	0.22	13.2	1.63	97.8	0.13	7.62
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.55	36.7	0.33	22.0	1.45	96.7	0.13	8.54
CD_8:2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.56	39.2	0.23	16.1	1.57	109.9	0.08	5.25
CD_9: 2.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	0.61	38.6	0.23	14.6	1.07	67.7	0.18	10.76
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.71	61.6	0.26	22.5	1.31	113.6	0.10	9.02
CD_{11}: 5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.56	52.2	0.23	21.5	1.43	133.4	0.05	4.29
CD_{12}: 5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	0.57	45.6	0.32	25.6	1.05	84.0	0.14	11.36
CD_{13}: 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.08	111.7	0.38	39.3	2.04	210.7	0.13	13.81
CD_{14}: 7.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.59	66.8	0.28	31.7	1.57	177.9	0.06	7.14
CD_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.66	84.7	0.21	26.9	1.63	209.1	0.12	14.88
CD_{16}: 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.69	73.6	0.35	37.3	1.49	159.0	0.12	13.23
LSD at 5%	0.074	5.0	0.053	0.79	0.073	1.81	0.053	0.80

RDF=Recommended Doses of Fertilizer CD= Cow dung Conc.= Concentration

The highest individual treatment of NPK fertilizers and combined treatments of NPK fertilizers and cow dung e.g. $N_{120}P_{90}K_{150}$kg ha^{-1}, 5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1}, 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} produced significantly ($P< 0.05$) higher result when compared with other treatments. Maximum concentration (0.38%) and uptake (39.3mg $plant^{-1}$ root) of phosphorus was recorded in 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatment. The variation in uptake of phosphorus between treatment to treatment was found to be significant and generally followed the trend of dry matter yield of root (Tables 4.3, 4.5). The values varied from 0.17 to 0.38% and 1.41 to 39.3 mg $plant^{-1}$ root respectively.

4.3.3.2.3 Concentration and uptake of potassium

Concentration and uptake of potassium in sunflower root increased significantly ($P< 0.05$) in all the treatments of NPK fertilizers and cow dung over the control (Table 4.5).

Variation in concentration of potassium between treatments in some cases was found to be significant ($P< 0.05$). Uptake of potassium showed the reflection of dry matter yield of root (Tables 4.3 and 4.5). Maximum concentration (2.04%) and uptake (210.7mg $plant^{-1}$) of potassium was measured in 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatment. The values of potassium ranged from 0.66 to 2.04% and 5.48 to 210.7mg $plant^{-1}$ root respectively (Table 4.5).

4.3.3.2.4 Concentration and uptake of sulfur

Sulfur concentration and uptake of sunflower root showed a significantly ($P< 0.05$) increase due to treatments of NPK fertilizers and cow dung over the control (Table 4.5). The variation in concentration and uptake of sulfur in root of sunflower varied significantly ($P< 0.05$) when compared between the treatments in most of the cases. Uptake of sulfur showed all most the trend of dry matter yield of root (Tables 4.3, 4.5). The maximum value of sulfur concentration (0.18%) was found in 2.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} treatment and that of uptake (14.88g $plant^{-1}$) in 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} treatment. The range of concentration and uptake of sulfur varied from 0.02 to 0.18% and 0.18 to 14.88mg $plant^{-1}$ root respectively (Table 4.5).

4.3.3.3 Concentration and uptake of NPKS in leaf

Effects of NPK fertilizers and cow dung applied at different rates on concentration and uptake of nitrogen, phosphorus, potassium and sulfur in sunflower leaf were measured (Table 4.6).

Results showed that concentration and uptake of all these nutrients in leaf increased significantly over the control. With the increase rates of both of fertilizers and cow dung, content and uptake of nitrogen, phosphorus, potassium and sulfur also increased.

4.3.3.3.1 Concentration and uptake of nitrogen

Concentration and uptake of nitrogen in leaf varied from 2.37 to 3.45% and 158.1 to 739.6mg plant^{-1} leaf respectively (Table 4.6). The highest values of nitrogen concentration and uptake were recorded in 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} treatments respectively (Table 4.6). Results showed that variation in concentration of nitrogen in leaf, between treatments, were not significant in most of the cases. However, an opposite trend was observed in case of uptake of nitrogen and followed the trend of dry matter yield of leaf (Tables 4.3, 4.6).

4.3.3.3.2 Concentration and uptake of phosphorus

Phosphorus concentration and uptake also followed the similar pattern of change like nitrogen (Table 4.6). Treatments of NPK fertilizers and cow dung showed significantly ($P< 0.05$) increase in concentration and uptake of phosphorus in leaf of sunflower plant over the control (Table 4.6). Variations among the treatments in concentration of phosphorus were also not significant in most of the cases. Changes in uptake of phosphorus followed the trend of dry matter yield of leaf (Tables 4.3, 4.6). The range of concentration and uptake of phosphorus varied from 0.22 to 0.67% and 14.7 to 129.5mg plant^{-1} leaf respectively (Table 4.6). The best treatment for concentration and uptake of phosphorus was found to be in the treatment, 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}.

4.3.3.3.3 Concentration and uptake of potassium

Concentration and uptake of potassium in leaf of sunflower increased significantly ($P< 0.05$) due to application of NPK fertilizers and cow dung over the control (Table 4.6).

Table 4.6 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in leaf

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
CD_1: Control	2.37	158.1	0.22	14.7	1.80	120.1	0.07	4.7
CD_2: 2.5t CD ha^{-1} (50 % RDF)	2.75	220.0	0.23	18.4	1.85	148.0	0.10	8.0
CD_3: 5t CD ha^{-1} (100 % RDF)	2.83	245.4	0.27	23.4	2.05	177.7	0.13	11.3
CD_4: 7.5t CD ha^{-1} (150 % RDF)	3.19	297.6	0.45	42.0	2.77	258.4	0.15	14.0
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	2.50	283.3	0.31	35.1	2.83	320.6	0.06	6.8
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	2.60	303.4	0.32	37.3	2.71	316.3	0.04	4.7
CD_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	2.83	452.8	0.35	56.0	2.94	470.0	0.09	14.4
CD_8: 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	2.85	513.0	0.35	63.0	2.76	496.8	0.12	21.6
CD_9: 2.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	2.86	438.4	0.39	59.8	3.23	495.2	0.14	21.5
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	2.87	382.6	0.40	53.3	2.99	398.6	0.17	22.7
CD_{11}: 5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	3.16	547.6	0.42	72.8	3.02	523.4	0.18	31.2
CD_{12}-: 5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	3.21	599.3	0.44	82.1	3.31	618.0	0.13	24.3
CD_{13}: 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	3.25	628.2	0.67	129.5	4.12	796.4	0.15	29.0
CD_{14}: 7.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	2.92	739.6	0.50	126.7	3.51	889.1	0.14	35.5
CD_{15}: 7.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	3.24	540.1	0.44	73.3	3.66	610.1	0.16	26.7
CD_{16}: 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	3.45	713.1	0.45	93.0	3.14	649.0	0.17	35.1
LSD at 5%	0.29	11.53	0.05	5.25	0.32	9.8	3.32	3.65

RDF=Recommended Doses of Fertilizer. CD= Cow dung. Conc.=Concentration

Concentration and uptake of potassium showed a variation due to variations in treatments. However, the variations in concentration of potassium when compared between the treatments were found to be not significant in most of the cases. The range of variation in concentration and uptake of potassium was 1.80 to 4.12% and 120.1 to 889.1mg plant^{-1} leaf respectively (Table 4.6). These highest values were recorded in the treatments 5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1} respectively. Uptake of potassium in leaf followed sequence of dry matter yield of leaf plant^{-1} (Tables 4.3, 4.6).

4.3.3.3.4 Concentration and uptake of sulfur

Both concentration and uptake of sulfur in leaf of sunflower significantly ($P< 0.05$) improved due to treatments of NPK fertilizers and cow dung applied at different rates on sunflower (Table 4.6). Concentration of sulfur in leaf increased with increasing rates of NPK fertilizers and cow dung except some treatments. The variations among the treatments were recorded to be not significant in most of the cases. The value of concentration and uptake ranged from 0.07 to 0.18% and 4.7 to 35.5 mg plant^{-1} leaf respectively (Table 4.6). The highest values were marked in the treatments 5t CD ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1} and 7.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1} respectively. The uptake of sulfur followed the sequence of dry matter of leaves of the sunflower plant (Tables 4.3, 4.6).

4.3.3.4 Concentrations and uptakes of NPKS in petiole and inflorescence

Application of NPK fertilizers and cow dung on sunflower showed that concentration and uptake of nitrogen, phosphorus, potassium and sulfur in petiole and inflorescence were significantly ($P< 0.05$) increased (Tables 4.7- 4.8).

Both concentration and uptake of these nutrients increased significantly ($P< 0.05$) when NPK fertilizers applied alone and in combination with cow dung over the control. On the other hand, when the treatments compared among themselves then the variations showed identical results in most of the cases. Results further showed that concentrations of nitrogen, phosphorus, potassium and sulfur in petiole and inflorescence increased with increasing levels of fertilizers and cow dung. Uptakes of nitrogen, phosphorus, potassium and sulfur followed the pattern of yield of dry matter of petiole and inflorescence respectively (Tables 4.3, 4.7-4.8).

Table 4.7 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in petiole

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
CD_1: Control	0.37	5.6	0.16	2.4	0.65	9.95	0.05	0.75
CD_2: 2.5t CD ha^{-1} (50 % RDF)	0.41	8.9	0.26	5.6	0.91	19.7	0.14	3.0
CD_3: 5t CD ha^{-1} (100 % RDF)	0.55	14.7	0.29	7.4	1.20	32.0	0.17	4.5
CD_4: 7.5t CD ha^{-1} (150 % RDF)	0.59	17.7	0.32	9.6	1.45	43.5	0.19	5.7
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	1.24	39.3	0.35	11.1	1.49	47.2	0.06	1.9
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	1.42	82.8	0.34	19.8	1.91	111.4	0.05	2.9
CD_7: $N_{120}P_{90}K_{150}$kg ha^{-1}(150% RDF)	1.51	85.6	0.39	22.1	2.00	113.4	0.07	4.0
CD_8: 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	1.60	85.3	0.43	22.9	1.80	95.94	0.18	9.6
CD_9: 2.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	1.62	97.2	0.40	24.0	1.98	118.8	0.15	9.0
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.73	118.2	0.43	29.4	2.18	148.9	0.17	11.6
CD_{11}: 5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	1.53	99.5	0.41	26.7	2.28	148.2	0.20	13.0
CD_{12}: 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	1.91	143.3	0.42	31.5	2.29	171.8	0.21	15.8
CD_{13}: 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.99	159.2	0.45	36.0	2.61	208.8	0.20	16.0
CD_{14}: 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg/ha^{-1}	1.65	154.0	0.50	46.7	2.20	205.3	0.12	11.2
CD_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	1.78	172.0	0.58	56.1	2.51	242.7	0.17	16.4
CD_{16}: 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.88	188.0	0.62	62.0	3.00	300.0	0.22	22.0
LSD at 5%	0.234	4.58	0.053	3.69	0.053	6.68	.053	1.76

RDF=Recommended Doses of Fertilizer CD= Cow dung Conc. = Concentration

Table 4.8 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in inflorescence

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
CD_1: Control	0.28	16.8	0.15	9.0	0.71	42.6	0.03	1.8
CD_2: 2.5t CD ha^{-1} (50 % RDF)	0.35	35.0	0.22	17.0	1.25	125.0	0.05	5.0
CD_3: 5t CD ha^{-1} (100 % RDF)	0.37	39.5	0.20	20.3	1.42	151.5	0.08	8.5
CD_4: 7.5t CD ha^{-1} (150 % RDF)	0.40	58.7	0.26	35.2	1.54	225.9	0.12	17.6
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.45	63.0	0.30	42.0	1.62	226.8	0.05	7.0
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.50	60.0	0.36	43.2	1.67	200.4	0.04	4.8
CD_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.52	79.7	0.45	69.0	1.75	268.3	0.05	7.7
CD_8:2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.43	63.1	0.42	61.6	1.64	240.6	0.14	20.5
CD_9: 2.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.48	70.4	0.47	68.9	1.69	247.9	0.14	20.5
CD_{10}: 2.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.58	88.9	0.51	78.2	1.77	271.3	0.17	26.6
CD_{11}: 5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.54	90.0	0.50	83.4	1.73	288.4	0.12	20.0
CD_{12}: 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.59	100.3	0.48	81.6	1.81	307.7	0.18	30.6
CD_{13}: 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.63	109.2	0.55	95.3	1.95	337.9	0.21	36.4
CD_{14}: 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.56	100.8	0.61	109.8	1.88	338.4	0.20	36.0
CD_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.67	125.1	0.68	121.4	2.12	395.8	0.19	35.5
CD_{16}: 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.73	141.1	0.65	150.8	2.25	434.9	0.23	44.5
LSD at 5%	0.04	6.87	0.053	6.07	0.34	11.46	0.053	4.25

RDF=Recommended Doses of Fertilizer CD= Cow dung Conc. = Concentration

The range of nitrogen concentration varied from 0.37-1.99%, however, the uptake varied from 5.6-188.0mg $plant^{-1}$ petiole respectively (Table 4.7). Compared to nitrogen the values of phosphorus were markedly lower and ranged from 0.16 to 0.62% however, the 2.4 to 62.0 mg $plant^{-1}$ petiole respectively (Table 4.7). Significantly ($P< 0.05$) compared to phosphorus, the concentration and uptake of potassium were relatively higher and ranged from 0.65 to 3.0% and 10.0 to 300.0mg $plant^{-1}$ petiole respectively (Table 4.7). Sulfur content and uptake in petiole ranged from 0.05 to 0.22% and 0.80 to 22.0mg $plant^{-1}$ petiole respectively. Uptake of nitrogen, phosphorus, potassium and sulfur in petiole followed the pattern of dry matter yield of petiole of sunflower (Tables 4.3, 4.7).

Variation in nitrogen concentration and uptake in inflorescence ranged from 0.28 to 0.73% and 16.8 to 141.1 mg $plant^{-1}$ inflorescence. Both the highest values were recorded in treatment, 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Phosphorus concentration and uptake varied from 0.15 to 0.68% and 9.0 to 150.8mg $plant^{-1}$ inflorescence respectively. The highest values were found in 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatments respectively (Table 4.8).

Potassium concentration and uptake of inflorescence of sunflower ranged from 0.71 to 2.25% and 42.6 to 434.9mg $plant^{-1}$ inflorescence respectively, and were measured from the treatment of highest levels of cow dung and NPK fertilizers, i.e. in the treatment 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.8).

Sulfur concentration and uptake of inflorescence of sunflower ranged from 0.03 to 0.23% and 1.8 to 44.5mg $plant^{-1}$ inflorescence, respectively, and were measured from the treatment of highest levels of cow dung and NPK fertilizers i.e. in the treatment, 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.8).

4.3.3.5 Concentration and uptake of NPKS in seed

Concentration and uptake of nitrogen, phosphorus, potassium and sulfur in seed of sunflower increased significantly ($P< 0.05$) due to treatments of cow dung and NPK fertilizers over the control (Table 4.9).

Different combinations of cow dung and NPK fertilizers when applied, the nutrient concentrations *viz.* nitrogen, phosphorus, potassium and sulfur increased with the increasing doses of cow dung and NPK fertilizers.

Table 4.9 Effects of NPK fertilizers and cow dung on the concentration and uptake of NPKS in seed

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
CD_1: Control	4.00	312.0	0.27	21.1	0.16	12.5	0.04	3.12
CD_2: 2.5t CD ha^{-1} (50 % RDF)	4.25	565.3	0.31	41.2	0.34	45.2	0.05	6.65
CD_3: 5t CD ha^{-1} (100 % RDF)	4.26	651.8	0.53	81.1	0.46	70.4	0.08	12.1
CD_4:7.5t CD ha^{-1} (150 % RDF)	4.75	893.0	0.65	122.2	0.40	75.2	0.10	17.9
C_5: $N_{40}P_{30}K_{50}$kg ha^{-1}. (50% RDF)	3.75	900.0	0.77	184.8	0.46	110.4	0.13	30.2
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1}. (100% RDF)	3.78	1409.9	0.67	249.9	0.52	194.0	0.15	56.0
CD_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	3.80	1292.0	0.63	214.2	0.58	197.2	0.14	47.9
CD_8: 2.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	3.72	1514.0	0.73	297.1	0.62	252.3	0.11	46.0
CD_9: 2.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	4.41	1839.0	0.76	316.9	0.66	275.2	0.12	51.7
CD_{10}: 2.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.58	1635.1	0.77	274.9	0.64	228.5	0.08	28.2
CD_{11}: 5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.42	1816.6	0.79	324.7	0.66	271.3	0.15	59.6
CD_{12}: 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	3.81	2007.9	0.83	437.4	0.67	353.1	0.14	73.8
CD_{13}: 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.95	2836.4	0.94	538.6	0.75	429.8	0.14	77.9
CD_{14}: 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.24	2569.4	0.89	539.3	0.60	363.6	0.16	93.9
CD_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	4.66	3115.0	0.93	601.7	0.66	427.0	0.26	100.9
CD_{16}: 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	3.78	2014.2	0.83	448.2	0.69	372.6	0.12	65.3
LSD at 5%	0.48	37.8	0.05	26.27	0.092	27.12	0.053	6.13

RDF=Recommended Doses of Fertilizer CD= Cow Dung Conc. = Concentration

However, the variations among the treatments were found to be not significant in most of the cases of concentrations of these nutrients. Similar trend was also observed in case of uptake of these nutrients in sunflower seed. The trend of uptake of these nutrients followed the trend of yield of dry seed of sunflower (Tables 4.3, 4.9).

Variation in concentration and uptake of nitrogen in seed varied from 3.72 (2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}) to 4.95% (5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}) and 312.0 to 3115.0mg $plant^{-1}$ seed respectively. The highest uptake was recorded in the treatment, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. Concentration and uptake of phosphorus in seed ranged from 0.27 to 0.94% and 21.1 to 601.7 mg $plant^{-1}$ seed respectively. Highest concentration and uptake of phosphorus were recorded in the treatments, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1} respectively (Table 4.9).

Potassium concentration and uptake were found to range from 0.16 to 0.75% and 12.5 to 429.8mg $plant^{-1}$ seed respectively. The highest values of concentration and uptake of potassium in seeds were measured from the same treatment, 5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}. Sulfur concentration and uptake showed a variation from 0.04 to 0.26% and 3.12 to 100.9mg $plant^{-1}$ seed respectively. Treatment 7.5t CD ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1} showed the highest values of concentration and uptake of sulfur in seed of sunflower (Table 4.9).

4.3.4 Effects of NKP fertilizers and cow dung on the oil and protein contents of sunflower seed

4.3.4.1 Oil content

Oil content is the most important product of sunflower plant. Treatments of various combinations of cow dung and NPK fertilizers significant ($P< 0.05$) increase in oil content of seeds over the control in most of the cases (Table 4.10). However, only six treatments namely 2.5t CD ha^{-1}, 7.5t CD ha^{-1}, 2.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, 2.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} caused significant decrease in oil content of seed over the control (Table 4.10).

Table 4.10 Effects of NPK fertilizers and cow dung on the oil and protein contents of sunflower seeds.

Treatments	% oil content	% protein content
CD_1: Control	40.9	24.1
CD_2: 2.5t CD ha^{-1} (50 % RDF)	38.1	26.8
CD_3: 5t CD ha^{-1} (100 % RDF)	42.8	26.7
CD_4: 7.5t CD ha^{-1} (150 % RDF)	42.5	29.6
CD_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	45.3	23.4
CD_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	44.6	23.7
CD_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	46.7	23.8
CD_8:2.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	49.3	23.4
CD_9: 2.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	42.6	24.4
CD_{10}: 2.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	39.4	29.1
CD_{11}: 5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	43.7	27.9
CD_{12}: 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	35.6	24.2
CD_{13}: 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	51.8	30.2
CD_{14}: 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	38.4	27.5
CD_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	51.2	29.9
CD_{16}: 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	43.3	25.1
LSD at 5%	1.17	1.47

RDF= Recommended dose of fertilizer CD= Cow dung

The highest (51.8%) and the lowest content (35.6%) of oil were observed in the treatments, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} respectively.

The variations in percent oil content among the treatments were significant. The highest content of oil (51.8%) was recorded in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. However, unusually, treatment, 5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} produced the lowest yield of oil (35.6%) in sunflower seed and even lower than the control (Table 4.10).

4.3.4.2 Protein content

Next to oil content, the most important product of the seed is the protein content. Chemical analysis of seeds showed that the protein content of sunflower seed due to treatments of cow dung and NPK fertilizers varied significantly ($P< 0.05$) in Table 4.10.

Content of protein ranged from 23.4 to 30.2%. The variations in protein content among the treatments were found to be significant in most of the treatments. The highest and the lowest values were recorded in the treatments, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and $N_{40}P_{30}K_{50}$kg ha^{-1} and 2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} respectively. This indicates that the highest amount of both cow dung and fertilizers produced the best result. The treatment combinations produced significant ($P< 0.05$) increase over the control. Only four treatments, ($N_{40}P_{30}K_{50}$kg ha^{-1}, $N_{80}P_{60}K_{100}$kg ha^{-1}, $N_{120}P_{90}K_{150}$kg ha^{-1} and 2.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}) caused non-significant decrease of protein over the control (Table 4.10).

4.3.5 Effects of NKP fertilizers and cow dung on the benefit: cost ratio of sunflower

Economic analysis of the yield of sunflower seed yield showed that the highest benefit: cost ratio (3.62) was found in the 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} treatment (Table 4.11).

The next highest benefit: cost ratio was 3.61 and was recorded in the 7.5t CD ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} treatment. Similarly, the lowest benefit: cost ratio (1.00) was recorded in the control treatment where no fertilizer was added either in the form of organic and inorganic form (Table 4.11).

Table 4.11 Effects of NPK fertilizers and cow dung on the benefit: cost ratio of sunflower

Treatments	Cost of cultivation (Tk. ha^{-1})	Gross returns (Tk. ha^{-1})	Net returns (Tk. ha^{-1})	Benefit: Cost ratio
C_1: Control	14950.00	15000.00	50.00	1.00
C_2: 2.5t CD ha^{-1} (50 % RDF)	18350.00	25500.00	7150.00	1.39
C_3: 5t CD ha^{-1} (100 % RDF)	21750.00	29400.00	7950.00	1.35
C_4: 7.5t CD ha^{-1} (150 % RDF)	25020.00	36300.00	11280.00	1.45
C_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	24620.00	46200.00	23950.00	1.88
C_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	26990.00	71700.00	44710.00	3.22
C_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	29360.00	65400.00	36040.00	2.23
C_8: 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	27120.00	78300.00	51180.00	2.89
C_9: 2.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	29490.00	80100.00	50610.00	2.72
C_{10}: 2.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	31860.00	68700.00	36840.00	2.16
C_{11}: 5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	29620.00	78900.00	49280.00	2.66
C_{12}: 5t CD ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	31990.00	101400.00	69410.00	3.17
C_{13}: 5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	34360.00	110100.00	75740.00	3.20
C_{14}: 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	32120.00	116400.00	53530.00	3.62
C_{15}: 7.5t CD ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	34490.00	124500.00	90010.00	3.61
C_{16}: 7.5t CD ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	37160.00	103800.00	66640.00	2.79

CD = Cow dung. RDF = Recommended dose of fertilizer

4.4 Conclusion

From the findings of results, the following conclusions are prepared

(i) 5t CD plus $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD plus $N_{120}P_{90}K_{150}$kg ha^{-1}, respectively, the best dose for growth, yield and NPKS content in the root, stem, leaf, petiole, inflorescence and seeds of sunflower.

(ii) Oil and protein content were found the highest in the treatment 5t CD plus $N_{120}P_{90}K_{150}$kg ha^{-1}.

(iii) According to the benefit: cost ratios the best doses in the treatment 7.5t CD plus $N_{40}P_{30}K_{50}$kg ha^{-1}.

Chapter 5

Influence of NPK Fertilizers and Rice Bran on the Growth, Yield and Nutrient Content of Sunflower (*Helianthus annus* L.)

5.1 Introduction

Agricultural land occupies approximately 70% of the 13 million hectares (M ha) of Bangladesh, and around 80% of this agricultural land is used for arable cropping (Loveland and Webb, 2003) but this arable land under vulnerability of degradation due to shortness of organic matter. Rice bran is the outermost layer of the paddy grain that is separated from the rice grain during milling process. It is an agricultural residue abundantly available in rice producing countries. Rice bran improve the soil structure, water and air content of soil, decreases soil bulk density values (Loveland and Webb, 2003). Rice bran was determined very significant negative correlations between organic matter content and bulk density values of soil (Candemir and Gulser, 2011). Addition of rice bran at increasing rate to the clay textured soil decreased bulk density and increase porosity of soils. Addition of rice bran to soil increases water holding capacity with increasing field capacity and available moisture content. In addition, rice bran compost in soil decrease soil P^H and electrical conductivity of soil (Candemir and Gulser, 2011). Organic waste used as regulators meets especially the nutrient requirements of the plants as well as many functions of soil. With the use of compost, organic substance lost from soils in various ways is again given into soils and thereby nutrient loss is reduced. Rice bran compost treatment increased available K, Mg and Ca contents of the soils. Organic acids as a decomposition product of organic matters provides plant available nutrient, particularly phosphorus and microelements. Application of rice bran caused an increase in biological activity and biomass in soils. On the other hand, chemical fertilizers have many disadvantage i.e. degradation and environmental hazard can cause destroy soil health. On the other hand, application of rice bran or fertilizers alone is not suitable for crop productions. For this reason combined used of rice bran and chemical fertilizers are suitable for sunflower and different crop production avoiding to destroy soil health and environmental hazard (Candemir and Gulser, 2011).

A scanty, information is available in the literature on organic farming. The present experiment was carried out to evaluate the influence of NPK fertilizers and rice bran on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L**.) at the research farm of Charfasson Govt. College, Bhola, during 2015-2016 in rabi season.

5.2 Materials and methods

5.2.1 Location, description and climatic condition

Geographic location, description and climatic condition of the experimental site are described in the sections 3.1 and 3.2; and Tables 3.1 and 3.2, respectively, in Chapter 3.

5.2.2 Collection of soil samples and analysis

5.2.2.1 Physical properties of soil

Soil sample collection and physical properties of soil, i.e. particle size, textural class, bulk density, particle density, maximum water retentive capacity are described in the sections 3.3, 3.3.1, 3.3.1.1, 3.3.1.2, 3.3.1.3, 3.3.1.4 and 3.3.1.5, respectively, and Table 3.4 in Chapter 3.

5.2.2.2 Chemical properties of soil

Soil chemical properties i.e. P^H, EC, OC, OM, total nitrogen, available nitrogen, available phosphorus, exchangeable potassium, available sulfur and heavy metal are described in the sections 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.2.7, 3.3.2.8, 3.3.2.9 and 3.3.2.10, respectively, and Table 3.4 in Chapter 3.

5.2.3 Experimental

Preparation of rice bran compost and its physical and chemical analysis are described in the sections 3.4, 3.4.1, 3.4.1.2 and 3.4.2, respectively, and Table 3.5 in Chapter 3.

5.2.3.1 Treatments of NPK fertilizers and rice bran

RB_1 : Control (-RB & NPK)

RB_2 : 2.5 t RB ha^{-1} (50% RDF)

RB_3 : 5t RB ha^{-1} (100% RDF)

RB_4 : 7.5 t RB ha^{-1} (150% RDF)

RB_5 : $N_{40}P_{30}K_{50}$ kg ha^{-1} (50% RDF)

RB_6 : $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)

RB_7 : $N_{120}P_{90}K_{150}$ kg ha^{-1} (150% RDF)

RB_8 : 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}

RB_9 : 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}

RB_{10} : 2.5t RB ha^{-1}+$N_{120}P_{90}$K150kg ha^{-1}

RB_{11} : 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}

RB_{12} : 5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}

RB_{13} : 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1}

RB_{14} : 7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}

RB_{15} : 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}

RB_{16} : 7.5t RB ha^{-1}+$N_{150}P_{120}K_{120}$ kg ha^{-1}

5.2.4 Crop husbandry

Design, land preparation, fertilizers application, sowing of seed, germination of seed, intercultural practices i.e. insects and diseases management, weeding, spading, thinning and vacancy supplying are described in the sections 3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.6.1 and 3.5.6.2, respectively, in Chapter 3.

5.2.5 Biometric observations

Biometric observations i.e. plant height (cm), number of leaves $plant^{-1}$, leaf area (cm^2), leaf area index (LAI), are described in the sections 3.6, 3.6.1, 3.6.2, 3.6.3, 3.6.4, respectively, in Chapter 3.

5.2.6 Harvesting and yield components

Harvesting, head diameter (cm), threshing seed, yield components *viz.* number of seeds plant^{-1}, seed yield (g plant^{-1}), 100 seed weight (g) are described in the sections 3.7, 3.7.1, 3.7.2, 3.8, 3.8.1, 3.8.2 and 3.8.3, respectively, in Chapter 3.

5.2.7 Plant sample analysis

Digestion of plant samples for nitrogen concentration, digestion of plant samples (root, stem, leaf, petiole, inflorescence and seed) with conc. nitric perchloric acid mixture, determination of phosphorus, potassium, sulfur concentration, oil of seed and oil yield (g plant^{-1}), seed protein are described in the sections 3.9, 3.10, 3.10.1, 3.10.1.1, 3.10.1.2, 3.10.1.3, 3.11, 3.12, respectively, in Chapter 3.

5.2.8 Uptake of nutrient

Uptake of nutrients by different parts of sunflower plant is described in the section 3.13 in chapter 3.

5.2.9 Economic analysis

Economic analysis is described in the sections 3.14 in Chapter 3.

5.2.10 Statistical analysis

Statistical analysis is described in the sections 3.15 in Chapter 3.

5.3 Results and discussion

Effects of NPK fertilizers and cow dung on the growth and yield of sunflower have been discussed in this chapter.

5.3.1 Effects of NPK fertilizers and rice bran on growth parameters of sunflower plant

Rice bran; 0.0, 2.5, 5.0, 7.5t ha^{-1} and NPK fertilizers; 0.0, 50, 100, 150% of recommended doses; alone or in combinations were applied on sunflower influenced the growth parameters *viz.* height (cm), leaf number (plant^{-1}), leaf area (cm^2) and leaf area index of sunflower plant significantly ($P< 0.05$) over the control (Tables 5.1-5.2).

Both parameters were measured at 30, 60 and 90 days of interval, respectively, after sowing of sunflower seeds.

5.3.1.1 Height (cm) and number of leaf (plant^{-1})

The growth parameters of sunflower plant i.e. height (cm) and number of leaf plant^{-1} increased significantly ($P< 0.05$) when compared with the untreated plants i.e. the control (Table 5.1). Values of plant height and number of leaf increased with increasing rates of both rice bran and fertilizers. The height and number of leaf also showed a general increase with time of growth period up to maturity of the plant.

Results showed that rice bran when applied alone was found to be comparatively less effective than fertilizers to increase the growth performances of sunflower though not statistically significant ($P< 0.05$). However, combinations of treatments were found to more effective to enhance the growth of the plant. Statistical analysis of the results showed that variations among the treatments were not significant in most of the cases irrespective of the growth of height (cm) and leaf number plant^{-1} respectively (Table 5.1).

The maximum height of the plant and number of leaves plant^{-1} were observed as 196.0cm (7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}) and 45.5 plant^{-1} (7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}), respectively, at 90 days of sowing (Table 5.1).

5.3.1.2 Leaf area (cm^2) and leaf area index

Results showed that leaf area (cm^2) and leaf area index were significantly ($P< 0.5$) increased over the control (Table 5.2). Results further revealed that gradually increased with growth period irrespective of the treatments. Moreover, the parameters also increased with the increase rates of rice bran and fertilizers in most of the cases.

However, the variations among the treatments, in most of the treatments were found to be statistically not significant. Maximum leaf area (cm^2) and leaf area index at maturity were 384.4 cm^2 (7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}) and 13.6 (7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}), respectively, at 90 days of sowing (Table 5.2). Minimum values were recorded in the control in both of the cases of growth parameters i.e. leaf area (cm^2) and leaf area index.

Between rice bran and fertilizers, fertilizers alone showed better results than rice bran in case of leaf area (cm^2) and leaf area index. Generally, highest doses of both the rice bran and fertilizers together produced comparatively higher results.

Table 5.1 Effects of NPK fertilizers and rice bran on height (cm) and number of leaf (plant^{-1})

Treatments	Days after sowing					
	Height (cm)			Number of leaf (plant^{-1})		
	30	60	90	30	60	90
RB_1: Control	25.0	70.0	92.0	9.3	19.0	24.5
RB_2: 2.5t RB ha^{-1} (50 % RDF)	29.7	88.7	98.5	10.3	20.3	28.6
RB_3: 5t RB ha^{-1} (100 % RDF)	34.7	110.3	125.5	11.7	21.3	30.4
RB_4: 7.5t RB ha^{-1} (150 % RDF)	34.0	125.3	139.4	12.0	25.0	36.2
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	39.0	127.7	146.0	12.7	26.7	35.0
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1}. (100% RDF)	39.7	145.0	164.3	13.3	25.3	37.2
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	36.3	158.0	173.4	13.7	30.3	40.4
RB_8: 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	40.0	144.7	165.0	14.0	28.0	37.0
RB_9: 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	45.3	154.3	172.5	14.7	30.3	42.4
RB_{10}:2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	47.7	165.0	181.2	15.3	28.7	39.2
RB_{11}: 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	38.7	154.3	175.5	13.3	25.0	30.4
RB_{12}: 5t RB ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	37.2	155.0	178.0	12.7	25.7	32.6
RB_{13}: 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	42.4	163.3	183.5	14.3	26.7	35.0
RB_{14}:7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	43.0	169.7	193.2	14.7	27.7	42.1
RB_{15}:7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	38.7	170.7	196.0	12.7	32.3	43.6
RB_{16}:7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	44.0	173.7	190.5	14.0	37.7	45.5
LSD at 5 %	6.7	9.5	13.5	1.62	5.39	3.61

RDF= Recommended dose of fertilizer   RB= Rice bran

Table 5.2 Effects of NPK fertilizers and rice bran on leaf area (cm^2) and leaf area index

Treatments	Days after sowing					
	Leaf area (cm^2)			Leaf area index		
	30	60	90	30	60	90
RB_1: Control	63.7	95.8	116.0	0.58	1.83	2.15
RB_2: 2.5t RB ha^{-1} (50 % RDF)	68.2	96.1	120.5	0.72	1.96	2.65
RB_3: 5t RB ha^{-1} (100 % RDF)	97.0	151.6	178.6	1.14	3.33	4.12
RB_4: 7.5t RB ha^{-1} (150 % RDF)	94.9	175.2	192.2	1.15	4.43	5.52
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	127.0	191.7	220.0	1.6	5.05	6.15
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1}. (100% RDF)	110.8	212.0	268.1	1.47	5.87	7.45
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	126.2	253.9	262.0	1.74	7.67	8.40
RB_8: 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	129.8	241.3	282.2	1.82	6.84	8.55
RB_9: 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	90.3	246.5	295.4	1.33	7.46	9.32
RB_{10}:2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	149.3	350.8	362.0	2.28	10.02	12.30
RB_{11}: 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	143.5	275.5	323.6	1.91	6.86	8.90
RB_{12}: 5t RB ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	116.8	296.7	348.4	1.47	7.62	9.12
RB_{13}: 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	153.9	339.8	378.5	2.09	8.94	10.30
RB_{14}:7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	142.4	357.3	358.5	2.08	9.87	11.02
RB_{15}:7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	138.0	357.0	384.4	1.75	11.52	12.50
RB_{16}:7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	159.3	369.8	380.3	2.23	13.93	13.60
LSD at 5 %	31.76	59.39	5.58	0.48	1.83	1.13

RDF= Recommended dose of fertilizer RB= Rice bran

5.3.2 Effects of NPK fertilizers and rice bran on dry matter and seed yield parameters of sunflower plant.

Effects of rice bran and NPK fertilizers on growth and yield of sunflower have been examined and the results obtained are presented in Table 5.3.

Rice bran (0.0, 2.5, 5.0, 7.5t ha^{-1}) and NPK fertilizers (0.0, 50, 100, 150%) recommended doses applied alone and in combination on sunflower positively influenced the growth and yield parameters of the crop (Table 5.3).

5.3.2.1 Dry weights of stem and root (g $plant^{-1}$)

Result showed that rice bran applied alone failed to promote the yield of root and stem of the sunflower crop significantly ($P<0.05$). However, fertilizer applied in different rates increased the growth of root and stem significantly at 5% level of significance over the control (Table 5.3). Combination of rice bran and fertilizers increased both the parameters of growth significantly ($P< 0.05$) over the control. The variations among the treatments were not statistically significant ($P< 0.05$) in most of the cases. However, when the variation between higher and lower doses were compared in combined treatments of rice bran and fertilizers, the results showed significant effect on stem and root weights of sunflower in some cases only.

Combined treatments of rice bran and fertilizers produced better production of stem and root than their individual application. It can be noted that increase in rate of rice bran and fertilizer increased the dry weight of stem and root weights of sunflower in all the treatments. The highest weight of stem (67.3g $plant^{-1}$) was recorded the treatment, 7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and the highest weight of root (16.0g $plant^{-1}$) was recorded in the both treatments, 5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

5.3.2.2 Dry weights of leaf and petiole (g $plant^{-1}$)

Dry weights of leaf and petiole $plant^{-1}$ of sunflower increased with increasing rates of rice bran and fertilizers in all the treatments applied (Table 5.3).

Table 5.3 Effects of NPK fertilizers and rice bran on dry matter and seed yield parameters of sunflower

Treatments	Root (g plant^{-1})	Stem (g plant^{-1})	Leaf (g plant^{-1})	Petiole (g Plant^{-1})	Inflores -cence (g plant^{-1})	Total dry matter yield (g plant^{-1})	Total dry matter yield. (t ha^{-1})	Diameter of infloresce -nce (cm)	Wt. of seed (g Plant^{-1})	Number of Seed (g Plant^{-1})	Wt. of 100 seed (g)
RB_1: Control	1.0	8.0	7.0	1.3	4.0	21.3	1.1	24.7	7.3	169.8	4.5
RB_2: 2.5t RB ha^{-1} (50 % RDF)	2.0	10.7	10.0	1.6	5.3	29.6	1.5	29.7	10.7	194.6	5.4
RB_3: 5t RB ha^{-1} (100 % RDF)	3.3	13.3	9.0	3.0	8.7	37.3	1.9	32.0	14.7	267.3	5.6
RB_4: 7.5t RB ha^{-1} (150 % RDF)	5.0	16.0	10.0	3.3	11.3	45.6	2.4	34.3	19.3	338.6	5.8
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF).	7.0	31.3	15.3	3.5	9.3	66.5	3.5	40.3	22.7	398.3	6.0
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	7.2	34.7	17.3	4.0	12.0	75.2	3.9	48.7	30.0	526.3	5.7
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1}. (150% RDF)	8.0	50.0	22.7	5.5	14.7	100.8	5.2	47.7	30.0	441.2	6.0
RB_8: 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	10.1	44.0	18.7	4.3	15.6	92.7	4.8	48.3	35.3	543.1	6.3
RB_9: 2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	13.7	46.7	20.7	4.2	16.9	102.1	5.3	46.7	36.0	571.4	6.4
RB_{10}: 2.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	13.8	45.3	20.0	4.8	17.3	101.3	5.3	47.0	39.3	633.9	6.6
RB_{11}: 5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	14.0	39.3	17.3	4.3	12.7	87.7	4.5	44.7	35.3	519.1	6.9
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	10.7	52.0	20.7	4.8	15.3	103.5	5.4	45.7	29.3	406.9	7.3
RB_{13}: 5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	16.0	57.3	22.7	4.8	18.0	118.8	6.2	52.7	38.0	520.6	7.0
RB_{14}: 7.5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	14.7	48.0	20.0	5.0	17.0	104.7	5.4	45.7	36.0	529.4	6.5
RB_{15}: 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	15.7	65.7	24.0	5.8	12.0	123.2	6.4	51.0	46.0	638.9	7.1
RB_{16}: 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	16.0	67.3	23.3	5.7	15.3	127.7	6.6	52.3	28.7	422.1	6.5
LSD at 5%.	4.31	18.03	7.51	1.24	12.31	12.21	0.62	11.63	6.86	23.8	0.76

RDF=Recommended dose of fertilizer RB=Rice Bran

Treatments also caused positive and significant ($P < 0.05$) effect, over the control, in most of the cases. Only rice bran applied alone failed to do so in case of leaf weight of the sunflower crop. Variation in dry weights of leaf and petiole among the treatments were found to be not significant in most of the treatments. Between rice bran and fertilizers, fertilizers showed better role in these respects. The highest dry weights of leaf and petiole were 24.0g and 5.8g plant^{-1}, respectively, and was recorded in the same treatment i.e. in (7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}).

5.3.2.3 Dry weight of inflorescences (g plant^{-1})

Treatments of rice bran and fertilizer applied to sunflower failed to increase the dry weight of inflorescences significantly ($P<0.05$) over the control except in few cases i.e. in treatments, 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, 2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} respectively (Table 5.3). Highest weight of inflorescence (18.0g plant^{-1}) was measured in the treatment, 5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}. The dry weight of inflorescence increased with increasing rate of both rice bran and fertilizers in all treatments.

5.3.2.4 Total dry matter yield (g plant^{-1}) and (t ha^{-1})

Total dry matter production (g plant^{-1}) and tones ha^{-1} increased with the increasing rate of rice bran and fertilizer in all the treatments when compared with control (Table 5.3). Combination of rice bran and NPK fertilizers produced higher dry matter than their individual applications. Highest results (127.7g plant^{-1} or 6.6t ha^{-1}) were found in the same treatment i.e. in 7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

5.3.2.5 Diameter of inflorescences (cm)

Diameter of inflorescences showed positive response due to application of rice bran and fertilizers in all combinations and all the treatments increased the diameter of inflorescences significantly ($P< 0.05$) over the control except the treatments where rice bran was added alone (Table 5.3). However, the variations in the same among the treatments were recorded to be statistically identical. Maximum diameter of inflorescence of sunflower (52.7cm) was observed in 5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

5.3.2.6 Weight of seed (g $plant^{-1}$) and number of seed ($plant^{-1}$)

Weight of seed (g $plant^{-1}$) and number of seed ($plant^{-1}$) of sunflower plant increased significantly ($P<0.05$) over the control due to treatment of rice bran and fertilizers in most of the treatments (Table 5.3). Rice bran applied alone was found to be insignificantly ($P< 0.05$) effective on number of seeds ($plant^{-1}$). Results revealed that increasing in rate of rice bran and fertilizers increased the weight of seed (g $plant^{-1}$) and number of seed ($plant^{-1}$). Maximum values were 46.0g $plant^{-1}$ and 638.9 $plant^{-1}$, respectively, recorded in the treatment, 7.5t RB $ha^{-1}+N_{80}P_{60}K_{100}$kg ha^{-1}. Comparison of the data showed no significant variation among in treatments in most of the cases.

5.3.2.7 Weight of 100 seed grains (g)

Results of rice bran and fertilizers showed that organic manure (RB) and inorganic fertilizers together caused a significant ($P< 0.05$) change in weight of 100 grains of sunflower with respect to the control (Table 5.3).

All the treatments showed significant increase in weight of 100 grains over the control but the variations between the treatments although were found to be not significant at all. The best result of weight of 100 grains (7.3g) was recorded in treatment, 5t RB $ha^{-1}+N_{80}P_{60}K_{100}$kg ha^{-1}. The weight of 100 grains also increased with doses of rice bran and fertilizers.

5.3.3 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in different organs of sunflower

5.3.3.1 Concentrations and uptakes of NPKS in stem

Effect of rice bran and NPK fertilizers on nitrogen, phosphorus, potassium and sulfur concentration and uptake of stem of sunflower were determined in Table 5.4.

Table 5.4 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in stem

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
RB_1: Control	1.07	85.6	0.11	8.8	0.62	49.6	0.07	5.6
RB_2: 2.5t RB ha^{-1} (50 % RDF)	1.10	117.7	0.20	21.4	1.18	126.3	0.10	10.7
RB_3: 5t RB ha^{-1} (100 % RDF)	1.18	156.9	0.22	29.26	1.40	186.2	0.12	16.0
RB_4: 7.5t RB ha^{-1}. (150 % RDF)	1.20	192.0	0.24	38.4	1.50	240.0	0.15	24.0
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	1.21	378.7	0.28	87.6	1.56	488.3	0.09	28.2
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	1.13	392.1	0.27	93.7	1.59	551.7	0.10	34.7
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	1.22	610.0	0.23	115.0	1.66	830.0	0.13	65.0
RB_8: 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	1.14	501.6	0.24	105.6	152	668.8	0.17	74.8
RB_9: 2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	1.16	541.7	0.20	93.4	1.49	695.8	0.15	70.1
RB_{10}: 2.5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.11	502.8	0.24	108.7	1.68	761.0	0.18	81.5
RB_{11}: 5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	1.22	497.5	0.22	86.5	1.48	581.6	0.14	55.0
RB_{12}: 5t RB ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	1.21	629.2	0.28	145.6	1.72	894.4	0.16	83.2
RB_{13}: 5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.16	664.7	0.35	200.6	1.74	997.0	0.17	97.4
RB_{14}: 7.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	1.10	528.0	0.29	139.2	1.90	912.0	0.14	67.2
RB_{15}: 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	1.14	749.0	0.30	197.1	1.52	998.6	0.17	111.7
RB_{16}: 7.5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.17	787.4	0.25	168.3	1.48	996.0	0.16	107.7
LSD at 5%	0.10	21.03	0.08	12.09	0.21	48.67	0.68	9.13

RDF=Recommended Doses of Fertilizer RB= Rice Bran Conc. = Concentration

The results showed that both concentration and uptake of nitrogen, phosphorus, potassium and sulfur of stem increased significantly ($P < 0.05$) due to application of various combinations of rice bran and NPK fertilizers over the control.

The treatments generally showed an increase in both the concentrations and uptakes of nitrogen, phosphorus, potassium and sulfur in sunflower stem with increasing rates of both rice bran and NPK fertilizers.

The values of concentration and uptake of the nutrients in stem of sunflower when compared between the treatments, in most of the cases, identical results were obtained. Nitrogen, phosphorus and potassium concentrations in stem were comparatively more effective in inorganic fertilizers treated plants than rice bran treated ones. An opposite effect was observed in case of sulfur concentration in stem. The values of uptake in all cases (nitrogen, phosphorus, potassium and sulfur) followed the same sequence of dry weights of stem of sunflower respectively (Tables 5.3-5.4). The values of concentration and uptake of nitrogen, phosphorus, potassium and sulfur varied individually. Concentration and uptake of nitrogen, phosphorus, potassium and sulfur in stem was shown in Table 5.4. Nitrogen concentration and uptake varied from 1.07 to 1.22 % and 85.6 to 787.4 mg plant^{-1} stem respectively (Table 5.4). The highest values were recorded in treatments, $N_{120}P_{90}K_{150}$kg ha^{-1} and 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}, and 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Phosphorus concentration and uptake ranged from 0.11 to 0.35% and 8.8 to 200.6 mg plant^{-1} stem respectively (Table 5.4). The highest values of concentration and uptake of phosphorus were recorded in the same treatment, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}.

Potassium concentration and uptake varied from 0.62 to 1.90% and 49.6 to 998.6 mg plant^{-1} stem respectively (Table 5.4). The maximum values of concentration and uptake were observed in treatments, 7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and 7.5t RB ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1} respectively. Similarly, sulfur concentration and uptake also varied from 0.07 to 0.18% and 5.6 to 111.7 mg plant^{-1} stem respectively (Table 5.4). The highest values were recorded in treatments, 2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1} respectively.

5.3.3.2 Concentrations and uptakes of NPKS in root

Effect of rice bran and NPK fertilizers on nitrogen, phosphorus, potassium and sulfur concentration and uptake of root of sunflower were determined in Table 5.5.

The results showed that both concentration and uptake of nitrogen, phosphorus, potassium and sulfur of root increased significantly ($P < 0.05$) due to application of various combinations of rice bran and NPK fertilizers over the control. The treatments generally showed an increase in both the concentrations and uptakes of nitrogen, phosphorus, potassium and sulfur in sunflower root with increasing rates of both rice bran and NPK fertilizers.

The values of concentration and uptake of the nutrients in root of sunflower when compared between the treatments, in most of the cases, identical results were obtained. Rice bran showed better results in nitrogen and sulfur concentration of root than fertilizer when applied alone. But phosphorus and potassium concentrations in root of sunflower were found to be better in fertilizer treated plants. The values of uptake in all cases (nitrogen, phosphorus, potassium and sulfur) followed the same sequence of dry weights of root of sunflower (Table 5.3-5.5). The values of concentration and uptake of nitrogen, phosphorus, potassium and sulfur varied individually.

The ranges of nitrogen concentration and uptake were found to be 0.52 to 1.17% and 5.2 to 187.2mg plant^{-1} root respectively (Table 5.5). The highest value of nitrogen concentration was recorded in treatments, 2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} but that of uptake was observed in 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

Like nitrogen, concentration and uptake of phosphorus in root of sunflower ranged from 0.09 to 0.35% and 0.9 to 56.0mg plant^{-1} root respectively (Table 5.5). Both the highest values were observed in the same treatment, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Potassium concentration and uptake of sunflower root were found to be 0.89 to 2.41 and 8.9 to 344.0 mg plant^{-1} root respectively (Table 5.5). The highest values were recorded in treatments, 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Sulfur concentration and uptake of root ranged from 0.07 to 0.16% and 0.7 to 19.2 mg plant^{-1} root respectively (Table 5.5). The highest recorded values were observed in treatments, 7.5t RB ha^{-1} and 5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Table 5.5 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in root

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
RB_1: Control	0.52	5.2	0.09	0.9	0.89	8.9	0.07	0.7
RB_2: 2.5t RB ha^{-1} (50 % RDF)	0.67	13.4	0.13	2.6	1.18	23.6	0.07	1.4
RB_3: 5t RB ha^{-1} (100 % RDF)	0.68	22.4	0.15	5.0	1.27	41.9	0.14	4.6
RB_4: 7.5t RB ha^{-1} (150 % RDF)	0.83	41.5	0.15	7.5	1.46	73.0	0.16	8.0
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.65	45.5	0.12	8.4	1.54	107.8	0.09	6.3
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.67	48.2	0.19	13.7	1.58	113.8	0.09	6.5
RB_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.68	54.4	0.25	20.0	1.94	155.2	0.08	6.4
RB_8: 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.52	42.5	0.19	19.2	2.03	205.0	0.09	9.1
RB_9: 2.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	0.71	97.3	0.23	31.5	2.07	283.6	0.08	11.0
RB_{10}: 2.5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.17	161.5	0.25	34.5	2.11	291.2	0.13	17.9
RB_{11}: 5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.93	130.2	0.21	29.4	2.41	237.4	0.10	14.0
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.69	73.8	0.20	21.4	1.88	201.2	0.09	9.6
RB_{13}: 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.17	187.2	0.35	56.0	2.15	344.0	0.12	19.2
RB_{14}: 7.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	0.92	135.2	0.21	30.9	2.05	301.4	0.10	14.7
RB_{15}: 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	0.98	153.9	0.17	26.7	1.71	268.5	0.10	15.7
RB_{16}: 7.5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	0.83	132.8	0.23	36.8	1.96	313.6	0.11	17.6
LSD at 5%	0.163	7.49	0.04	5.02	0.44	15.37	0.053	1.75

RDF=Recommended Doses of Fertilizer RB= Rice Bran Conc. = Concentration

5.3.3.3 Concentration and uptake of NPKS in leaf

Treatments of rice bran and NPK fertilizers, on concentration and uptake of nitrogen, phosphorus, potassium and sulfur in leaf were measured (Table 5.6). Treatments showed significantly ($P< 0.05$) positive effects with doses of rice bran and NPK fertilizers on nutrients concentrations (nitrogen, phosphorus, potassium and sulfur) of leaf of sunflower over the control. But comparison between the treatments showed identical results. Between rice bran and fertilizers, rice bran played better role than inorganic fertilizers in case of only sulfur concentration.

Fertilizers played better role than rice bran in case of nitrogen and potassium but in case of phosphorus, the effects of rice bran and NPK fertilizers remained almost same. Uptake of nitrogen, phosphorus, potassium and sulfur in leaf followed the same trend of dry matter yields of leaf (Tables 5.3, 5.6). Concentration and uptake of nitrogen and phosphorus in leaf of sunflower varied from 2.18 to 3.98 and 0.28 to 0.43%; and 152.6 to 903.5 and 19.6 to 97.6 mg plant^{-1} leaf of both nitrogen and phosphorus respectively (Table 5.6). The highest values of both nitrogen and phosphorus were recorded in the same treatment, 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 5.6).

Similarly, concentration and uptake of potassium and sulfur in leaf ranged from 2.56 to 4.28% and 0.10 to 0.24%; and 179.2 to 971.6 and 7.0 to 55.2 mg plant^{-1} leaf respectively (Table 5.7). The highest values were observed in treatments, $N_{120}P_{90}K_{150}$kg ha^{-1} for potassium and 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} for sulfur.

Table 5.6 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in leaf

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
RB_1: Control	2.18	152.6	0.28	19.6	2.56	179.2	0.10	7.0
RB_2: 2.5t RB ha^{-1} (50 % RDF)	2.33	233.0	0.28	28.0	2.80	280.0	0.13	13.0
RB_3:5t RB ha^{-1} (100 % RDF)	2.36	212.4	0.31	27.9	3.41	306.9	0.15	13.5
RB_4:7.5t RB ha^{-1} (150 % RDF)	2.37	237.0	0.34	34.0	3.43	343.0	0.17	17.0
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	2.50	382.5	0.33	50.5	3.24	495.7	0.08	12.0
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	2.62	453.3	0.34	58.8	3.49	603.8	0.12	20.8
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	2.75	624.3	0.35	79.5	4.28	971.6	0.09	20.4
RB_8:2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	2.79	521.7	0.39	72.9	4.16	777.9	0.12	22.4
RB_9:2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	2.97	614.8	0.35	72.5	3.01	623.1	0.14	29.0
RB_{10}:2.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	3.17	634.0	0.36	72.0	4.13	826.0	0.16	32.0
RB_{11}: 5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	3.10	536.3	0.34	58.8	3.59	621.1	0.18	31.1
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	3.12	645.8	0.30	62.1	3.68	761.8	0.22	45.5
RB_{13}:5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	3.98	903.5	0.43	97.6	4.07	923.9	0.23	52.2
RB_{14}: 7.5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	3.12	624.0	0.37	74.0	3.89	778.0	0.18	36.0
RB_{15}: 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	3.96	650.4	0.38	91.2	3.74	897.6	0.20	48.0
RB_{16}: 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.96	680.8	0.40	92.0	3.83	880.9	0.24	55.2
LSD at 5%	0.54	21.59	0.06	7.34	0.57	35.15	0.053	4.76

RDF=Recommended Doses of Fertilizer   RB= Rice Bran   Conc. = Concentration

5.3.3.4 Concentration and uptake of NPKS in petiole

Treatments of rice bran and NPK fertilizers, on concentration and uptake of nitrogen, phosphorus, potassium and sulfur in petiole were measured (Table 5.7).

Treatments showed significantly ($P < 0.05$) positive effects with doses of rice bran and NPK fertilizers on nutrients concentrations (nitrogen, phosphorus, potassium and sulfur) of petiole of sunflower over the control. But comparison between the treatments showed identical results. Between rice bran and fertilizers, rice bran played better role than inorganic fertilizers in case of only sulfur concentration.

Fertilizers played better role than rice bran in case nitrogen and potassium but in case of phosphorus, the effects of rice bran and NPK fertilizers remained almost same. Uptake of nitrogen, phosphorus, potassium and sulfur in petiole followed the same trend of dry matter yields of petiole (Tables 5.3, 5.7).

Concentration and uptake of nitrogen and phosphorus in petiole ranged from 0.53 to 1.04 and 0.14 to 0.65%, and 6.9 to 59.3 and 1.8 to 37.1 mg plant^{-1} petiole respectively (Table 5.7). The highest values for both concentration and uptake of nitrogen and phosphorus were observed in the same treatment, 7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

Like nitrogen and phosphorus, concentration and uptake of potassium and sulfur in petiole of sunflower varied from 0.56 to 3.0% and 0.04 to 0.22% and 7.3 to 171.0 and 0.5 to 12.8mg plant^{-1} petiole respectively (Table 5.7). The highest values of concentration and uptake of potassium was found in same treatment, 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. The highest values of concentration and uptake of sulfur was found in same treatment, 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} here with in treatment, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} for sulfur concentration.

Table 5.7 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in petiole

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
RB_1:Control	0.53	6.9	0.14	1.8	0.56	7.3	0.04	0.5
RB_2:2.5t RB ha^{-1} (50 % RDF)	0.57	9.1	0.20	3.2	0.83	13.3	0.12	1.9
RB_3:5t RB ha^{-1} (100 % RDF)	0.61	18.3	0.25	7.5	1.31	39.3	0.16	4.8
RB_4:7.5t RB ha^{-1} (150 % RDF)	0.65	21.5	0.26	8.6	1.50	49.5	0.18	5.9
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.97	34.0	0.29	10.2	1.62	56.7	0.07	2.5
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.74	29.6	0.35	14.0	1.92	76.8	0.08	3.2
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.79	43.5	0.42	23.1	1.99	109.5	0.09	5.0
RB_8:2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.63	27.1	0.44	18.9	1.66	71.4	0.11	4.7
RB_9:2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.70	29.4	0.46	19.3	1.69	71.0	0.13	5.5
RB_{10}:2.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.85	40.8	0.41	19.7	2.13	102.2	0.16	7.7
RB_{11}: 5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.91	39.1	0.43	18.5	1.83	78.7	0.14	6.0
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.95	45.6	0.49	23.5	1.89	90.7	0.17	8.2
RB_{13}:5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.98	47.0	0.52	25.0	2.30	110.4	0.22	10.6
RB_{14}: 7.5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.93	46.5	0.40	20.0	2.00	100.0	0.20	10.0
RB_{15}: 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.96	55.7	0.61	35.4	2.05	118.9	0.22	12.8
RB_{16}: 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.04	59.3	0.65	37.1	3.00	171.0	0.19	10.8
LSD at 5%	0.053	6.46	0.074	3.83	0.288	7.78	0.053	2.02

RDF=Recommended Doses of Fertilizer RB= Rice Bran Conc. = Concentration

5.3.3.5 Concentration and uptake of NPKS in inflorescence

Concentration of nitrogen, phosphorus, potassium and sulfur in inflorescence of sunflower were improved due to application of rice bran and NPK fertilizers in alone and various combinations (Table 5.8).

All the treatments increased the concentrations of nitrogen, phosphorus, potassium and sulfur in inflorescence of sunflower significantly ($P< 0.05$) over the control. Concentrations of nitrogen, phosphorus, potassium and sulfur increased with increasing doses of rice bran and NPK fertilizers. The differences between the treatments were identical in most of the cases. Uptake of nitrogen, phosphorus, potassium and sulfur followed the pattern of dry weight of inflorescence (Tables 5.3, 5.8).

Nitrogen and phosphorus concentrations of inflorescence ranged from 0.36 to 2.16% and 0.09 to 0.58% respectively. The highest values were recorded in the same treatment, 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. The values of uptake of nitrogen and phosphorus varied from 14.4 to 365.4 and 3.6 to 93.6 mg inflorescence $plant^{-1}$ respectively (Table 5.8). The highest uptake of nitrogen and phosphorus were recorded in same treatment, 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}.

Potassium and sulfur concentrations were found to vary from 0.75 to 2.21% and 0.05 to 0.26% respectively. Potassium and sulfur uptakes were found to range between 30.0 to 338.1 and 2.0 to 41.4mg $plant^{-1}$ respectively. Highest values of both concentrations and uptakes of potassium and concentration of sulfur of inflorescence were being recorded in the same treatment, 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and that of uptake of sulfur in 5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} treatment. Concentration of sulfur in inflorescence treated with only fertilizer was almost 50% of values of rice bran treated ones.

Table 5.8 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in inflorescence

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
RB_1: Control	0.36	14.4	0.09	3.6	0.75	30.0	0.05	2.0
RB_2: 2.5t RB ha^{-1} (50 % RDF)	0.39	20.7	0.16	8.5	1.02	54.1	0.11	5.8
RB_3: 5t RB ha^{-1} (100 % RDF)	0.58	50.5	0.18	15.7	1.16	100.9	0.15	13.1
RB_4: 7.5t RB ha^{-1} (150 % RDF)	0.62	70.1	0.22	24.9	1.28	144.6	0.16	18.1
RB_5: $N_{40}P_{30}K_{50}$kg ha-[1] (50% RDF)	1.42	132.1	0.27	25.1	1.40	130.2	0.06	5.6
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	1.49	178.8	0.30	36.0	1.48	177.6	0.05	6.0
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	1.55	227.9	0.37	54.4	1.56	229.3	0.07	10.3
RB_8: 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	1.62	252.7	0.34	53.3	1.44	224.6	0.13	20.3
RB_9: 2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	1.70	287.3	0.39	65.9	1.52	256.9	0.14	23.7
RB_{10}: 2.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.82	314.9	0.43	74.4	1.61	278.5	0.17	29.4
RB_{11}: 5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	1.87	237.5	0.40	50.8	1.57	199.4	0.18	22.9
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	1.88	287.6	0.45	68.9	1.63	249.4	0.19	29.1
RB_{13}: 5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.03	365.4	0.52	93.6	1.71	307.8	0.23	41.4
RB_{14}: 7.5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	2.12	360.4	0.48	81.6	1.91	324.7	0.22	37.4
RB_{15}: 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	2.14	256.8	0.54	64.8	2.09	250.8	0.25	30.0
RB_{16}: 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.16	330.5	0.58	88.7	2.21	338.1	0.26	39.8
LSD at 5%	0.053	27.45	0.053	7.28	0.053	29.95	0.437	3.6

RDF=Recommended Doses of Fertilizer RB= Rice Bran Conc. = Concentration

5.3.3.6 Concentration and uptake of NPKS in seed

Concentration of nitrogen, phosphorus, potassium and sulfur in seed of sunflower were improved due to application of rice bran and NPK fertilizers in alone and various combinations (Table 5.9).

All the treatments increased the concentrations of nitrogen, phosphorus, potassium and sulfur in seed of sunflower significantly ($P < 0.05$) over the control. Concentrations of nitrogen, phosphorus, potassium and sulfur increased with increasing doses of rice bran and NPK fertilizers. The differences between the treatments were identical in most of the cases. Uptake of nitrogen, phosphorus, potassium and sulfur followed the pattern of seeds yield (Tables 5.3, 5.9).

Nitrogen and phosphorus concentration and uptake of seed showed a variation between 3.17 to 5.24 and 0.43 to 0.83%, and 231.4 to 2396.6 and 31.4 to 345.0mg plant^{-1} seed respectively (Table 5.9). The highest values of nitrogen and phosphorus concentrations were recorded in the treatments, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB ha^{-1} respectively. Similarly, the maximum values of uptake for both the nutrients were observed in the same treatment, 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}.

Concentration and uptake of potassium and sulfur in seeds of sunflower varied between 0.57 and 1.60, and 0.13 and 0.47%; 41.6 and 547.2 and 9.5 and 115.0 mg plant^{-1} seed respectively. The highest values were observed in treatment, 2.5t RB ha^{-1}, and 5t RB ha^{-1}; and 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} respectively.

Table 5.9 Effects of NPK fertilizers and rice bran on the concentration and uptake of NPKS in seed

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
RB_1: Control	3.17	231.4	0.43	31.4	0.57	41.6	0.13	9.5
RB_2: 2.5t RB ha^{-1} (50 % RDF)	3.21	343.5	0.53	56.7	1.60	171.2	0.22	23.5
RB_3: 5t RB ha^{-1} (100 % RDF)	3.23	474.8	0.68	100.0	1.39	204.3	0.47	69.1
RB_4: 7.5t RB ha^{-1} (150 % RDF)	3.27	631.1	0.83	160.2	1.14	220.0	0.23	44.4
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	3.26	740.0	0.52	118.0	1.11	252.0	0.22	49.9
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	3.27	981.0	0.57	171.0	1.11	333.0	0.21	63.0
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	3.29	987.0	0.68	204.0	1.15	345.0	0.14	42.0
RB_8: 2.5t RB ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	3.39	1196.7	0.64	225.9	1.55	547.2	0.19	67.1
RB_9: 2.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	3.86	1389.6	0.72	259.2	1.06	381.6	0.23	82.8
RB_{10}: 2.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.04	1587.7	0.78	306.5	1.01	396.9	0.18	70.7
RB_{11}: 5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.34	1532.0	0.65	229.5	1.15	406.0	0.19	67.1
RB_{12}: 5t RB ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	4.46	1306.8	0.75	219.8	0.96	281.3	0.19	55.7
RB_{13}: 5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	5.24	1991.2	0.82	311.6	1.15	437.0	0.29	110.2
RB_{14}: 7.5t RB ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.34	1562.4	0.69	248.4	1.39	500.4	0.22	79.2
RB_{15}: 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	5.21	2396.6	0.75	345.0	1.15	529.0	0.25	115.0
RB_{16}: 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.34	1245.6	0.64	183.7	1.25	358.8	0.23	66.0
LSD at 5%	0.46	31.05	0.053	30.49	0.26	31.95	0.14	9.32

RDF=Recommended Doses of Fertilizer RB= Rice Bran Conc. = Concentration

5.3.4 Effects of NKP fertilizers and rice bran on the oil and protein contents of sunflower seeds

5.3.4.1 Oil content

Application of rice bran and NPK fertilizers at different combinations influenced on the oil content of sunflower seeds significantly ($P < 0.05$) over the control except in treatment, 2.5t ha^{-1} RB (Table 5.10).

Results showed that all the treatments increased the oil content of seed following the increase of rice bran and NPK fertilizers except 2.5t ha^{-1} RB. The variations among the treatments were found to be significant in most of the cases. The highest (51.1%) content of oil was observed in 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment. The lowest (39.0%) content of oil was observed in 2.5t RB ha^{-1} treatment that the value was lower than control treatment.

5.3.4.2 Protein content

Protein content of sunflower seed also showed the almost similar trend as in case of oil (Table 5.10). The treatments showed a gradual increase in protein content with the increase of doses of both the rice bran and NPK fertilizers. Six treatments namely 2.5t RB ha^{-1}, 5t RB ha^{-1}, 7.5t RB ha^{-1}, $N_{40}P_{30}K_{50}$kg ha^{-1}, $N_{80}P_{60}K_{100}$kg ha^{-1} and $N_{120}P_{90}K_{150}$kg ha^{-1} showed not significant decrease in protein content when compared with the control. However, the rest of the treatments significantly ($P < 0.05$) increased the protein content of sunflower seeds. The highest (33.9%) and the lowest (18.9%) contents of protein were recorded in 5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and control treatments respectively.

Moreover, the variations among the treatments were found to be not significant in most of the treatments as far as protein content was concerned.

Table 5.10 Effects of NPK fertilizers and rice bran on the oil and protein contents of sunflower seeds

Treatments	% oil content	% protein content
RB_1: Control	40.5	18.9
RB_2: 2.5t RB ha^{-1} (50 % RDF)	39.0	19.8
RB_3: 5t RB ha^{-1} (100 % RDF)	44.8	20.0
RB_4: 7.5t RB ha^{-1} (150 % RDF)	43.7	21.2
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	45.4	21.3
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	45.2	21.7
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	43.0	22.2
RB_8: 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	44.8	23.6
RB_9: 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	45.3	27.4
RB_{10}: 2.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	47.1	26.7
RB_{11}: 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	48.7	27.9
RB_{12}: 5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	45.2	33.9
RB_{13}: 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	51.1	31.0
RB_{14}: 7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	43.8	30.5
RB_{15}: 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	49.8	28.9
RB_{16}: 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	46.3	25.8
LSD at 5%	1.3	4.42

RDF= Recommended dose of fertilizer RB= Rice bran

5.3.5 Effects of NKP fertilizers and rice bran on the benefit: cost ratio of sunflower

Treatment of rice bran and NPK fertilizers influenced the benefit: cost ratio of sunflower cultivation (Table 5.11).

Highest benefit: cost ratio was obtained (2.51) with the application 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}. The next highest benefit: cost ratio was 2.48 and was recorded in 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} treatment. Similarly, the lowest benefit: cost ratio was found in control treatment.

Table 5.11 Effects of NPK fertilizers and rice bran on the benefit: cost ratio of sunflower

Treatments	Cost of Cultivation (Tk. ha^{-1})	Gross returns (Tk. ha^{-1})	Net returns (Tk. ha^{-1})	Benefit: Cost ratio
RB_1: Control	14300.00	14100.00	-200.00	0.99
RB_2: 2.5t RB ha^{-1} (50 % RDF)	17600.00	20700.00	3100.00	1.18
RB_3: 5t RB ha^{-1} (100 % RDF)	20950.00	28200.00	7250.00	1.35
RB_4: 7.5t RB ha^{-1} (150 % RDF)	24670.00	37200.00	12530.00	1.50
RB_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	24620.00	43800.00	19180.00	1.78
RB_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	26990.00	57600.00	30610.00	2.13
RB_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	29336.00	57600.00	28240.00	1.96
RB_8: 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	27370.00	67800.00	40430.00	2.48
RB_9: 2.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	29740.00	69300.00	39560.00	2.33
RB_{10}: 2.5t RB ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	32110.00	75600.00	43409.00	2.35
RB_{11}: 5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	30120.00	67800.00	37680.00	2.25
RB_{12}: 5t RB ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	32490.00	56400.00	23910.00	1.74
RB_{13}: 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	34860.00	73200.00	38340.00	2.03
RB_{14}: 7.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	32870.00	69300.00	36430.00	2.11
RB_{15}: 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	35240.00	88500.00	53260.00	2.51
RB_{16}: 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	37910.00	55200.00	17290.00	1.46

RDF = Recommended dose fertilizer RB = Rice bran

5.4 Conclusion

From the above findings the following conclusion are made

(i) 5t RB plus $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB plus $N_{120}P_{90}K_{150}$kg ha^{-1} are better doses for growth, yield and NPKS content in the root, stem, leaf, petiole, inflorescence and seeds of sunflower.

(ii) Oil and protein content were also relatively highest in the treatment of 5t RB plus $N_{120}P_{90}K_{150}$kg ha^{-1}.

(iii) According to the benefit: cost ratios the best dose in the treatment of 7.5t RB plus $N_{80}P_{60}K_{100}$kg ha^{-1}.

Chapter 6

Effects of NPK Fertilizers and Poultry Litter on the Growth, Yield and Nutrient Content of Sunflower (*Helianthus annus* L.)

6.1 Introduction

Poultry litter application improves the soil physical properties, significantly decreases bulk density, increases total porosity, infiltration capacity, moisture content, water holding capacity and available water capacity (Agbede *et al*., 2008). It neutralizes soil reaction and increase soil buffer capacity, for this soil nutrients availability and increase soil microbial activity and their population. Soil microbial biomass and enzyme activities were generally higher in the poultry litter amended soil.

Poultry litter is an excellent organic fertilizer as it contains high nitrogen, phosphorus, potassium and other essential nutrients (Farhad *et al*., 2009). It is reported that to supply phosphorus, exchangeable cations and micronutrients, and decreased exchangeable aluminium and iron contents and soil bulk density. Poultry manure application increased soil N levels by 53% while exchangeable cation contents also increased appreciable (Boateng *et al*., 2006). Soil nitrogen and phosphorus contents increase with increasing rates of poultry litter. The high nitrogen and balanced nutrients is the reason that chicken manure compost is the best kind of manure to use.

Integrated nutrient management is a recent approach stabilizing production of crops. There are many references that poultry litter improves the quality of cereal crops, fruits and fibre crops. Poultry litter with inorganic fertilizers promoted the quality of soybean and other oil seed crops.

Quantifying the potential for mitigation climate change through soil organic carbon sequestration while maintaining yield, will help policy makers to develop strategies to ensure environmental sustainability and to meet the challenge of feeding the growing population through manuring (Begum *et al.*, 2018).

The present experiment was carried out to evaluate the effects of NPK fertilizers and poultry litter compost on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L**.) at the research farm of Charfasson Govt. College, Bhola, during 2016-2017 in rabi season.

6.2 Materials and methods

6.2.1 Location, description and climatic condition

Geographic location, description and climatic condition of the experimental site are described in the sections 3.1 and 3.2; and Tables 3.1 and 3.3, respectively, in Chapter 3.

6.2.2 Collection of soil samples and analysis

6.2.2.1 Physical properties of soil

Soil sample collection and physical properties of soil, i.e. particle size, textural class, bulk density, particle density, maximum water retentive capacity are described in the sections 3.3, 3.3.1, 3.3.1.1, 3.3.1.2, 3.3.1.3, 3.3.1.4 and 3.3.1.5, respectively, and Table 3.4 in Chapter 3.

6.2.2.2 Chemical properties of soil

Soil chemical properties i.e. P^H, EC, OC, OM, total nitrogen, available nitrogen, available phosphorus, exchangeable potassium, available sulfur and heavy metal are described in the sections 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.2.7, 3.3.2.8, 3.3.2.9 and 3.3.2.10, respectively, and Table 3.4 in Chapter 3.

6.2.3 Experimental

Preparation of poultry litter compost and its physical and chemical analysis are described in the sections 3.4, 3.4.1, 3.4.1.3 and 3.4.2, respectively, and Table 3.5 in Chapter 3.

6.2.3.1 Treatments of NPK fertilizers and poultry litter

PL_1 : Control - (PL & NPK)
PL_2 : 1.5 t PL ha^{-1} (50% RDF)
PL_3 : 3 t PL ha^{-1} (100% RDF)
PL_4 : 4.5 t PL ha^{-1} (150% RDF)
PL_5 : $N_{40}P_{30}K_{50}$ kg ha^{-1} (50% RDF)
PL_6 : $N_{80}P_{60}K_{100}$ kg ha^{-1} (100% RDF)
PL_7 : $N_{120}P_{90}K_{150}$ kg ha^{-1} (150% RDF)
PL_8 : 1.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}
PL_9 : 1.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}
PL_{10} : 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1}
PL_{11} : 3t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}
PL_{12} : 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}
PL_{13} : 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}
PL_{14} : 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}
PL_{15} : 4.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}
PL_{16} : 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}

6.2.4 Crop husbandry

Design, land preparation, fertilizers application, sowing of seed, germination of seed, intercultural practices i.e. insects and diseases management, weeding, spading, thinning and vacancy supplying are described in the sections 3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.6.1 and 3.5.6.2, respectively, in Chapter 3.

6.2.5 Biometric observations

Biometric observations i.e. plant height (cm), number of leaves plant^{-1}, leaf area (cm^2), leaf area index (LAI), are described in the sections 3.6, 3.6.1, 3.6.2, 3.6.3 and 3.6.4, respectively, in Chapter 3.

6.2.6 Harvesting and yield components

Harvesting, head diameter (cm), threshing seed, yield components *viz.* number of seeds plant^{-1}, seed yield (g plant^{-1}), 100 seed weight (g) are described in the sections 3.7, 3.7.1, 3.7.2, 3.8, 3.8.1, 3.8.2 and 3.8.3, respectively, in Chapter 3.

6.2.7 Plant sample analysis

Digestion of plant samples for nitrogen concentration, digestion of plant samples (root, stem, leaf, petiole, inflorescence and seed) with conc. nitric perchloric acid mixture, determination of phosphorus, potassium, sulfur concentration, oil of seed and oil yield (g $plant^{-1}$), seed protein are described in the sections 3.9, 3.10, 3.10.1, 3.10.1.1, 3.10.1.2, 3.10.1.3, 3.11 and 3.12, respectively, in Chapter 3.

6.2.8 Uptake of nutrient

Uptake of nutrients by different parts of sunflower plant is described in the section 3.13 in chapter 3.

6.2.9 Economic analysis

Economic analysis is described in the section 3.14 in Chapter 3.

6.2.10 Statistical analysis

Statistical analysis is described in the section 3.15 in Chapter 3.

6.3 Results and discussion

Effects of NPK fertilizers and cow dung on the growth, yield, nutrient concentration and uptake, quality of seed and benefit: cost ratio of sunflower cultivation have been discussed in this section.

Cow dung; 0.0, 2.5, 5.0, 7.5t ha^{-1} and NPK fertilizers; 0.0, 50, 100, 150% of recommended doses; alone and in combinations were applied.

6.3.1 Effects of NPK fertilizers and poultry litter on growth parameters of sunflower plant

Growth pattern like height, leaf number, leaves area and leaf area index of sunflower has been examined in the field (Tables 6.1-6.2).

Poultry litter and NPK fertilizers applied to the plant in different combinations significantly ($P < 0.05$) increased the growth parameters over the control. Results showed that growth parameters of sunflower increased with growth periods *viz.* 30, 60, and 90 days of sowing (Tables 6.1-6.2).

6.3.1.1 Height (cm) and number of leaf (plant^{-1})

Height and leaf number increased with increasing rates of both poultry litter and fertilizers during all the intervals of growth (Table 6.1). Compared to cow dung and rice bran, poultry litter also showed better effect on growth of sunflower when combined with inorganic fertilizers. However, most of the treatments showed identical variation when compared among the treatments.

Maximum height and leaf number were recorded as 204.3cm and 44.8 plant^{-1} in the same treatment (4.5t PL ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}) measured at the maturity stage of 90 days after sowing. The highest combination of both poultry litter and fertilizers showed the maximum values of all the growth parameters of sunflower.

6.3.1.2 Leaf area (cm^2) and leaf area index

Leaf area and leaf area index increased with increasing rates of both poultry litter and fertilizers during all the intervals of growth (Table 6.2). Compared to cow dung and rice bran, poultry litter also showed better effect on growth of sunflower when combined with inorganic fertilizers. However, most of the treatments showed identical variation when compared among the treatments.

Maximum leaf area and leaf area index were recorded as 376.4 cm^2 and 13.61 in the same treatment (4.5t PL ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}) measured at the maturity stage of 90 days after sowing. The highest combination of both poultry litter and fertilizers showed the maximum values of all the growth parameters of sunflower.

Table 6.1 Effects of NPK fertilizers and poultry litter on height (cm) and number of leaf (plant^{-1})

Treatments	Days after sowing					
	Height (cm)			Number of leaf (plant^{-1})		
	30	60	90	30	60	90
PL_1: Control	34.0	78.0	88.0	12.7	16.0	24.6
PL_2: 1.5t PL ha^{-1} (50 % RDF)	48.0	112.0	118.2	15.7	20.7	30.4
PL_3: 3t PL ha^{-1} (100 % RDF)	56.7	112.3	118.7	13.3	20.0	33.5
PL_4: 4.5t PL ha^{-1} (150 % RDF)	46.0	132.0	137.0	15.0	20.3	35.7
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	60.7	132.7	138.3	15.7	22.0	34.8
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	68.3	140.7	145.3	16.3	24.3	38.6
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	85.0	163.3	170.3	18.3	25.0	39.5
PL_8: 1.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	50.7	160.7	174.7	16.0	27.3	37.2
PL_9: 1.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	59.0	175.3	182.8	15.3	27.3	39.7
PL_{10}: 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	73.0	173.7	185.0	16.3	27.3	42.6
PL_{11}: 3t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	64.3	151.7	168.0	16.3	24.0	36.8
PL_{12}: 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	67.0	172.3	182.2	17.0	23.7	30.3
PL_{13}: 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	87.0	173.3	183.5	17.0	25.7	32.4
PL_{14}: 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	82.0	163.7	174.3	16.7	24.7	36.0
PL_{15}: 4.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	65.3	173.0	185.7	16.0	27.0	40.5
PL_{16}: 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	75.0	194.0	204.3	17.0	26.67	44.8
LSD at 5 %	16.0	21.58	21.86	1.62	4.64	4.74

RDF= Recommended dose of fertilizer PL= Poultry litter

Table 6.2 Effects of NPK fertilizers and poultry litter on leaf area (cm^2) and leaf area index

Treatments	Days after sowing					
	Leaf area (cm^2)			Leaf area index		
	30	60	90	30	60	90
PL_1: Control	102.4	111.3	69.0	1.35	0.98	1.40
PL_2: 1.5t PL ha^{-1} (50 % RDF)	121.3	93.7	124.0	1.93	1.94	3.01
PL_3: 3t PL ha^{-1} (100 % RDF)	155.2	94.3	190.5	2.06	1.92	4.55
PL_4: 4.5t PL ha^{-1} (150 % RDF)	105.8	114.6	212.3	1.59	2.3	6.10
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	188.7	101.7	224.5	2.97	2.24	6.32
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	190.2	152.7	262.4	3.09	3.6	8.50
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	207.3	177.3	274.0	3.79	4.49	8.65
PL_8: 1.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	155.0	156.3	278.6	2.44	4.29	8.44
PL_9: 1.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	150.7	162.3	294.5	2.32	3.44	9.75
PL_{10}: 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	217.5	298.0	340.0	3.62	8.15	12.40
PL_{11}: 3t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	104.0	132.2	282.0	2.36	3.16	10.02
PL_{12}: 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	214.7	150.7	310.5	3.56	3.53	8.30
PL_{13}: 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	284.0	231.0	275.0	4.78	6.03	7.70
PL_{14}: 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	164.5	127.0	360.5	2.76	3.02	5.52
PL_{15}: 4.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	192.3	167.7	302.0	2.71	4.58	9.85
PL_{16}: 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	248.3	236.7	376.4	4.33	6.35	13.61
LSD at 5 %	97.52	85.57	5.74	1.60	2.36	2.61

RDF= Recommended dose of fertilizer PL= Poultry litter

6.3.2 Effects of NPK fertilizers and poultry litter on dry matter and seed yield parameters of sunflower

Poultry litter and NPK fertilizers applied alone and in combination on sunflower grown in the field positively influenced the growth and yield parameters of the crop (Table 6.3).

6.3.2.1 Dry weights of root and stem (g plant^{-1})

Poultry litter and fertilizers applied to sunflower grown showed a positive influence on dry weights of root and stem. Poultry litter and fertilizers applied to the crop increased the dry weights of root and stem with increasing levels of poultry litter and fertilizers. However, their effects were not significant ($P< 0.05$) in some cases over the control (Table 6.3).

The efficiency of poultry litter alone was found to be ineffective to improve the yield of root and stem of sunflower crop. Highest doses of poultry litter with fertilizers resulted significant ($P< 0.05$) increase in both the parameters over the control. Through the variations between the treatments were statistically identical in most of the cases. The highest dry weights of stem (63.82g plant^{-1}) and root (12.66g plant^{-1}) were recorded in the treatments, 1.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

6.3.2.2 Dry weights of leaf and petiole (g plant^{-1})

Weights of leaf plant^{-1} and weight of petiole plant^{-1} showed a wide positive variation ranging from 6.29 to 21.47 and 1.9 to 8.7g plant^{-1}, respectively, though these variations were not significant ($P< 0.05$) over the control due to application of poultry litter and fertilizers in various combinations (Table 6.3). The results showed that identical variation was observed over the control in all the treatments except the treatments where highest rate of poultry litter with fertilizers were applied. Similarly, significant ($P< 0.05$) effect was observed in treatment to increase leaf weight plant^{-1} (Table 6.3). Weight of petiole plant^{-1} increased in the treatments receiving higher rates of fertilizers and poultry litter. However, the increase in petiole weight plant^{-1} remained identical. The highest weights of leaf plant^{-1} (21.47g) and petiole plant^{-1} (8.7g) were observed in 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

Table 6.3 Effects NPK fertilizers and poultry litter on dry matter and seed yield parameters of sunflower plant

Treatments	Root (g $plant^{-1}$)	Stem (g $plant^{-1}$)	Leaf (g $plant^{-1}$)	Petiole (g $plant^{-1}$)	Inflores-cence (g $plant^{-1}$)	Total dry matter yield (g $plant^{-1}$)	Total dry matter yield (t ha^{-1})	Diameter of inflores-cence (cm)	Wt. of seed (g $plant^{-1}$)	Number of seed (g $plant^{-1}$)	Wt. of 100 Seed (g)
PL_1: Control	2.44	16.56	6.29	1.9	5.4	32.6	1.7	28.3	7.4	161.3	4.55
PL_2: 1.5t PL ha^{-1} (50 % RDF)	4.80	24.45	7.85	2.9	10.1	50.1	2.6	35.8	11.9	218.3	5.30
PL_3: 3t PL ha^{-1} (100 % RDF)	3.71	18.74	6.06	2.4	7.7	38.6	2.0	36.7	12.6	234.0	5.40
PL_4: 4.5t PL ha^{-1} (150 % RDF)	4.16	17.56	7.80	2.8	16.0	48.4	2.5	36.0	12.8	233.7	5.60
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	5.41	27.90	8.90	3.4	12.4	57.9	3.0	35.0	18.0	316.7	5.80
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	9.09	47.47	10.27	4.7	30.1	101.6	5.3	53.0	21.5	375.0	5.51
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	11.25	60.86	11.98	6.0	29.7	119.8	6.2	51.7	34.7	504.3	6.50
PL_8: 1.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	6.47	30.24	7.67	3.4	22.5	70.3	3.7	37.3	25.9	396.3	6.58
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	8.29	38.41	11.2	4.5	20.6	83.0	4.3	50.3	34.2	542.0	6.35
PL_{10}: 1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	11.95	63.82	11.16	4.6	27.7	119.2	6.2	52.7	34.0	545.7	6.46
PL_{11}: 3t PL $ha^{-1\ 1}$ + $N_{40}P_{30}K_{50}$kg ha^{-1}	6.16	30.44	10.94	4.0	27.5	79.0	4.1	42.3	40.2	603.3	6.62
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	7.47	38.42	12.1	5.2	17.7	81.0	4.2	44.3	36.2	517.3	6.80
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	10.94	58.70	16.72	6.5	32.6	125.5	6.5	54.0	44.3	609.0	7.40
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	11.36	39.69	14.43	4.9	17.4	87.7	4.6	40.7	44.4	663.0	6.75
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	10.76	55.73	13.16	5.5	30.7	115.8	6.0	50.7	36.2	525.0	6.84
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	12.66	61.57	21.47	8.7	29.6	134.0	7.0	53.3	35.8	524.7	6.80
LSD at 5 %	5.76	22.76	6.51	2.13	7.51	23.7	0.68	14.55	8.34	175.84	0.76

RDF=Recommended Dose of Fertilizer PL= Poultry Litter

6.3.2.3 Dry weight of inflorescence (g plant^{-1})

Dry weight of inflorescence plant^{-1} showed the similar pattern in variation of weight of petiole plant^{-1} (Table 6.3). Lower rates of poultry litter alone were not significant to increase the weight of inflorescence plant^{-1}. Weight of inflorescence plant^{-1} increased significantly ($P< 0.05$) due to application of poultry litter with fertilizers in their higher rates of combination. The range of weight of inflorescence varied from 5.4 to 32.6 g plant^{-1}. The highest weight was recorded in plants treated with 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}.

6.3.2.4 Total dry matter yield (g plant^{-1}) and (t ha^{-1})

Both total dry matter yields in g plant^{-1} and in t ha^{-1} followed the similar pattern of change (Table 6.3). Both the values increased notably with increasing rate of poultry litter and fertilizers either applied alone or together. Production of dry matter was relatively higher in combined treatments than the individual applications of poultry litter and fertilizers. Maximum yields of dry matter were 134.0g plant^{-1} and 7.0 t ha^{-1}, respectively, recorded in the same treatment i.e. in 4.5t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

6.3.2.5 Diameter of inflorescence (cm)

Diameter of inflorescence of sunflower increased variably over the control and was statistically significant ($P< 0.05$) in Table 6.3.

Poultry litter alone and lower doses of fertilizer were showed no significant ($P< 0.05$) increase in diameter of inflorescence over the control. Lower dose of fertilizer even with the higher dose of poultry litter also showed similar effect. The higher doses of fertilizers with all levels of poultry litter showed better results and were significant but the variation between them were not significant. The highest diameter of inflorescence (54.0cm) was recorded in the treatment, 3t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

6.3.2.6 Weight of seed (g plant^{-1}) and number of seed (plant^{-1})

Weight of seed plant^{-1} and number of seed plant^{-1} increased significantly ($P< 0.05$) due to influence of poultry litter and fertilizers over the control (Table 6.3).

The result showed that both the parameters increase of dose of poultry litter and fertilizers increased except the influence of poultry litter alone on them (Table 6.3). Variation in weight of seed plant^{-1} and number of seeds plant^{-1} were not significant at lower levels of poultry litter and fertilizers. However, an opposite trend was observed in the treatments of higher combinations. The maximum weight of seed plant^{-1} (44.4g) and number of seeds plant^{-1} (663.0g) was observed in the same treatment poultry litter and fertilizers i.e. in 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1} treatment.

6.3.2.7 Weight of 100 seed grains (g)

Poultry litter and fertilizers applied in different combinations showed a significant ($P < 0.05$) increase in weight of 100 seed grains of sunflower when compared with the control (Table 6.3).

All the treatments caused a significant ($P < 0.05$) increase in weight of 100 seed grains of sunflower as compared to control but the variations among the treatments were not significant. The increase in weight of 100 seed grains generally increased with rates of poultry litter and fertilizers. The highest weight of 100 seed grains (7.4g) was observed in 3t PL + $N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

6.3.3 Nutrient concentration and uptake of different organs of sunflower plant

Poultry litter (0.0, 1.5, 3.0, 4.5t ha^{-1}) and NPK fertilizers (0.0, 50, 100, 150% RDF) in various combinations were applied on sunflower and their effect on concentrations and uptakes of nitrogen, phosphorus, potassium and sulfur in different organs of sunflower were determined (Tables 6.4-6.9).

6.3.3.1 Concentrations and uptakes of NPKS in stem and root

Results showed significant ($P < 0.05$) increase in nitrogen, phosphorus, potassium and sulfur concentrations of stem and root over the control (Tables 6.4-6.5). Concentration of nitrogen, phosphorus, potassium and sulfur in both stem and root of the plant increased with increasing doses of poultry litter and NPK fertilizers though the variations between the treatments were found to be not significant ($P < 0.05$) in most of the cases. Uptake of the nutrients followed trend of dry matter yields of stem and root of the plant (Tables 6.3-6.5).

6.3.3.1.1 Concentration and uptake of NPKS in stem

Nitrogen concentration and uptake in stem ranged from 0.20 to 0.65% and 33.1 to 381.6 mg plant^{-1} stem respectively (Table 6.4).

The highest values were found in the same treatment, 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Phosphorus concentration and uptake of stem varied from 0.13 to 0.42% and 21.5 to 256.6 mg plant^{-1} stem respectively (Table 6.4). The maximum values of concentration and uptake were recorded in the same treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}.

Potassium concentration and uptake ranged from 0.64 to 1.80% and 106.0 to 997.9 mg plant^{-1} stem respectively (Table 6.4). Maximum values of concentration and uptake were observed in treatments, 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively. Similarly, sulfur concentration and uptake varied from 0.04 to 0.17% and 6.6 to 99.8 mg plant^{-1} stem respectively. The observed highest values of concentration and uptake were found in the treatments, 3t PL ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1} and 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}; and 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Table 6.4 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in stem

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
PL_1: Control	0.20	33.1	0.13	21.5	0.64	106.0	0.04	6.6
PL_2: 1.5t PL ha^{-1} (50 % RDF)	0.23	56.2	0.16	39.2	1.20	293.4	0.07	17.1
PL_3: 3t PL ha^{-1} (100 % RDF)	0.33	61.8	0.17	31.9	1.42	266.1	0.08	15.0
PL_4: 4.5t PL ha^{-1} (150 % RDF)	0.35	61.5	0.20	35.1	1.52	266.9	0.10	17.6
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.22	61.4	0.20	55.8	1.48	412.9	0.04	11.2
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.19	90.2	0.26	123.4	1.57	745.3	0.08	38.0
PL_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.17	103.5	0.42	256.6	1.60	973.8	0.09	54.8
PL_8: 1.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	0.26	78.6	0.23	69.6	1.57	474.8	0.12	36.3
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.29	111.4	0.22	84.5	1.40	537.7	0.14	53.8
PL_{10}: 1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.31	197.8	0.22	140.4	1.56	995.6	0.13	83.0
PL_{11}: 3t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.37	112.6	0.23	88.3	1.46	444.4	0.17	51.7
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.40	153.7	0.21	80.7	1.69	649.3	0.15	57.6
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.65	381.6	0.23	135.0	1.70	997.9	0.17	99.8
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.45	178.6	0.24	95.3	1.80	714.4	0.15	59.5
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.52	289.8	0.20	111.5	1.78	992.0	0.16	89.2
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.56	344.8	0.20	123.1	1.62	997.4	0.14	86.2
LSD at 5%	0.053	34.04	0.06	25.80	0.26	30.42	0.053	6.69

RDF=Recommended Doses of Fertilizer PL= Poultry Litter Conc. = Content

6.3.3.1.2 Concentration and uptake of NPKS in root

Concentration and uptake of nitrogen in root ranged from 0.39 to 1.02% and 9.5 to 111.6 mg plant^{-1} root and the highest values of concentration and uptake were observed in the same treatment, 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 6.5).

The same values for phosphorus ranged from 0.11 to 0.54% and 2.7 to 64.6 mg plant^{-1} root and the highest values of concentration and uptake were recorded in the treatments, 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively. Similarly, concentrations and uptake of potassium in root varied from 0.36 to 1.54% and 8.8 to 195.0mg plant^{-1} root respectively. The highest values of concentration and uptake were recorded in the same treatment, 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} (Table 6.5).

Sulfur concentration and uptake ranged from 0.07 to 0.18% and 1.7 to 19.4 mg plant^{-1} root, respectively, and the highest values of concentration and uptake were observed in the same treatment, 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}.

Table 6.5 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in root

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
PL_1:Control	0.39	9.5	0.11	2.7	0.36	8.8	0.07	1.7
PL_2: 1.5t PL ha^{-1} (50 % RDF)	0.43	20.6	0.22	10.6	0.56	26.9	0.12	5.8
PL_3: 3t PL ha^{-1} (100 % RDF)	0.49	18.2	0.24	8.9	0.78	28.9	0.14	5.2
PL_4: 4.5t PL ha^{-1} (150 % RDF)	0.75	31.2	0.27	11.2	0.78	32.4	0.16	6.7
PL_5-: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.44	23.8	0.34	18.4	0.82	44.4	0.06	3.2
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.52	47.3	0.37	33.6	0.96	87.3	0.07	6.4
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.59	66.4	0.41	46.1	1.06	119.3	0.08	9.0
PL_8: 1.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.52	33.6	0.44	28.5	1.12	72.5	0.11	7.1
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.55	45.6	0.42	34.8	1.10	91.2	0.13	10.8
PL_{10}: 1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.67	80.1	0.45	53.8	1.13	135.0	0.15	17.9
PL_{11}: 3t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.41	25.3	0.48	29.6	1.17	72.1	0.12	7.4
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.53	39.6	0.50	37.4	1.26	94.1	0.14	10.5
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.02	111.6	0.54	59.1	1.50	164.1	0.16	17.5
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.77	87.5	0.52	59.1	1.32	150.0	0.15	17.0
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.81	87.2	0.46	49.5	1.50	161.4	0.18	19.4
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.77	97.5	0.51	64.6	1.54	195.0	0.13	16.5
LSD at 5%	0.04	10.11	0.053	4.64	0.20	14.5	0.13	1.95

RDF=Recommended Doses of Fertilizer PL= Poultry Litter Conc. = Concentration

6.3.3.2 Concentrations and uptakes of NPKS in leaf and petiole

Effects of PL and NPK fertilizers in different combinations on nutrients concentrations of leaf and petiole have been measured (Tables 6.6-6.7).

Results showed that the treatments behavior was vary identical to root and stem. The uptake of all these nutrients (nitrogen, phosphorus, potassium and sulfur) also followed the same trend as in case of root and stem. Variation in the treatments was observed but not significant ($P < 0.05$) when compared among themselves.

6.3.3.2.1 Concentration and uptake of NPKS in leaf

Concentration and uptake of nitrogen and phosphorus varied from 1.37 to 4.47 and 0.40 to 0.57%; and 86.2 to 747.4 and 18.9 to 95.3mg plant^{-1} leaf respectively (Table 6.6). The highest values of concentration and uptake of nitrogen and phosphorus were recorded in the same treatment, 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Similarly, concentration and uptake of potassium and sulfur ranged from 1.44 to 3.14 and 0.07 to 0.20%; and 90.6 to 659.1 and 4.4 to 40.8 mg plant^{-1} leaf respectively (Table 6.6). The highest values of concentration and uptake were found in treatments, 4.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}; and 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

6.3.3.2.2 Concentration and uptake of NPKS in petiole

Concentration and uptake of nitrogen and phosphorus in petiole varied from 0.38 to 2.60% and 0.05 to 0.64%, and 7.2 to 226.2 and 1.0 to 50.5 mg plant^{-1} petiole respectively (Table 6.7). The maximum values of concentration and uptake of nitrogen and phosphorus in treatments, 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 4.5t PL ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1}; and 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} were observed respectively.

Concentration and uptake of potassium and sulfur ranged from 0.61 to 3.20 and 0.03 to 0.32%, and 11.6 to 278.4 and 0.6 to 17.4 mg plant^{-1} petiole respectively (Table 6.7). The highest values of concentration and uptake were observed in treatments, 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}; and 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Table 6.6 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in leaf

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
PL_1: Control	1.37	86.2	0.40	18.9	1.44	90.6	0.07	4.4
PL_2: 1.5t PL ha^{-1} (50 % RDF)	2.22	174.3	0.37	29.0	1.90	149.2	0.10	7.9
PL_3-3t PL ha^{-1} (100 % RDF)	2.30	139.4	0.45	27.3	2.12	128.5	0.10	6.1
PL_4: 4.5t PL ha^{-1} (150 % RDF)	2.42	188.8	0.46	35.9	2.15	167.7	0.14	10.9
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	2.31	205.6	0.41	36.5	2.23	198.5	0.07	6.2
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	2.42	248.5	0.42	43.1	2.38	244.4	0.08	8.2
PL_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	2.47	295.9	0.45	53.9	2.49	298.3	0.06	7.2
PL_8: 1.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	2.48	190.2	0.33	25.3	2.57	197.1	0.12	9.2
PL_9: 1.5t PL ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	2.50	280.0	0.53	59.4	2.64	295.7	0.14	15.7
PL_{10}: 1.5t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	2.62	292.4	0.48	53.6	2.69	300.2	0.16	17.9
PL_{11}: 3t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	2.72	297.6	0.29	31.7	2.81	307.4	0.13	14.2
PL_{12}: 3t PL ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	2.93	354.5	0.30	36.3	2.97	359.4	0.17	20.6
PL_{13}: 3t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	4.47	747.4	0.57	95.3	3.07	513.3	0.20	33.4
PL_{14}: 4.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	2.97	428.6	0.47	67.8	3.06	441.6	0.15	21.6
PL_{15}: 4.5t PL ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	3.02	397.4	0.44	57.9	3.14	413.2	0.17	22.4
PL_{16}: 4.5t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	3.10	665.6	0.42	90.2	3.07	659.1	0.19	40.8
LSD at 5%	0.18	24.57	0.053	6.5	0.12	42.44	0.053	4.15

RDF=Recommended Doses of Fertilizer PL= Poultry Litter Conc. = concentration

Table 6.7 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in petiole

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
PL_1: Control.	0.38	7.2	0.05	1.0	0.61	11.6	0.03	0.6
PL_2: 1.5t PL ha^{-1} (50 % RDF).	0.43	12.5	0.09	2.6	0.85	24.7	0.08	2.3
PL_3: 3t PL ha^{-1} (100 % RDF)	0.57	13.7	0.16	3.8	0.89	21.4	0.16	3.8
PL_4: 4.5t PL. ha^{-1} (150 % RDF)	0.58	16.2	0.17	4.8	1.12	31.4	0.19	5.3
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	1.20	40.8	0.26	8.8	1.66	56.4	0.07	2.4
PL_6:$N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF).	1.31	61.6	0.26	12.2	1.64	77.1	0.09	4.2
PL_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	1.47	88.2	0.34	20.4	1.75	105.0	0.11	6.6
PL_8:1.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	1.72	58.5	0.28	9.5	1.79	60.9	0.14	4.8
PL_9:1.5t PL ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	1.77	79.7	0.30	13.5	1.98	89.1	0.17	7.7
PL_{10}: 1.5t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	1.75	80.5	0.49	22.5	2.40	110.4	0.32	8.7
PL_{11}: 3t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	1.71	68.4	0.44	17.6	1.90	76.0	0.12	4.8
PL_{12}: 3t PL ha^{-1} +$N_{80}P_{60}K_{100}$ kg ha^{-1}	1.92	99.8	0.48	25.0	2.00	104.0	0.14	7.3
PL_{13}: 3t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	2.31	150.2	0.62	40.3	3.00	195.0	0.18	11.7
PL_{14}: 4.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	2.20	170.8	0.41	20.1	2.95	144.6	0.16	7.8
PL_{15}: 4.5t PL ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}	2.50	137.5	0.64	35.2	2.91	160.1	0.18	9.9
PL_{16}: 4.5t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}	2.60	226.2	0.58	50.5	3.20	278.4	0.20	17.4
LSD at 5%	0.117	7.66	0.105	3.28	0.166	118.85	0.053	2.12

RDF=Recommended Doses of Fertilizer PL= Poultry Litter Conc. = Concentration

6.3.3.3 Concentrations and uptakes of NPKS in inflorescence and seed

Nitrogen, phosphorus, potassium and sulfur concentration and uptake of inflorescence and seed as influenced by poultry litter and NPK fertilizers were measured (Tables 6.8-6.9). The treatments of poultry litter and NPK fertilizers showed a very similar pattern of change as in cases of root, stem, leaf and petiole of sunflower plant (Tables 6.8-6.9). Treatments variations also showed identical change. Uptake pattern of the nutrients also followed the trend of sequence of dry matter yield of inflorescence (Tables 6.3, 6.8).

6.3.3.3.1 Concentration and uptake of NPKS in inflorescence

Concentration and uptake of nitrogen and phosphorus in inflorescence varied from 0.28 to 1.30 and 0.06 to 0.95%, and 15.1 to 384.8 and 3.2 to 281.2 mg plant^{-1} inflorescence respectively (Table 6.8).

Variation in concentration and uptake of potassium and sulfur in inflorescence ranged from 0.62 to 2.19 and 0.07 to 0.32%, and 33.5 to 648.2 and 3.8 to 94.7 mg plant^{-1} inflorescence respectively. The highest values of all these nutrients (NPKS) of concentration and uptake were recorded in the same treatment, 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

6.3.3.3.2 Concentration and uptake of NPKS in seed

Values for nitrogen and phosphorus concentration and uptake of sunflower seed ranged from 2.89 to 5.18 and 0.26 to 0.86% and 213.9 to 2294.7 and 19.2 to 381.0 mg plant^{-1} seed respectively (Table 6.9). The highest values of the nutrients were observed in the same treatments, 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}.

Concentration and uptake of potassium and sulfur ranged from 0.44 to 1.02 and 0.15 to 0.31%, and 32.6 to 447.4 and 11.1 to 128.5 mg plant^{-1} seed respectively (Table 6.9). The highest values of concentration and uptake of potassium and sulfur were recorded in the treatments, 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 3t PL ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}, and 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 3t PL ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Table 6.8 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in inflorescence

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
PL_1: Control	0.28	15.1	0.06	3.2	0.62	33.5	0.07	3.8
PL_2: 1.5t PL ha^{-1} (50 % RDF)	0.35	35.4	0.17	17.2	0.75	75.8	0.13	13.1
PL_3: 3t PL ha^{-1} (100 % RDF)	0.39	30.0	0.21	16.2	0.85	65.5	0.17	13.1
PL_4: 4.5t PL ha^{-1} (150 % RDF)	0.45	72.0	0.25	40.0	0.95	152.0	0.19	30.4
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.51	63.2	0.31	38.4	1.12	138.9	0.09	16.2
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.56	168.6	0.37	111.4	1.42	427.4	0.08	24.1
PL_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.59	175.2	0.44	130.7	1.53	454.4	0.11	32.7
PL_8:1.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	0.53	119.3	0.40	90.0	1.42	319.5	0.20	45.0
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.58	119.5	0.46	94.8	1.55	319.3	0.24	49.4
PL_{10}: 1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.65	180.1	0.51	141.3	1.57	434.9	0.25	69.3
PL_{11}: 3t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.63	173.3	0.57	156.8	1.56	429.0	0.22	60.5
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.72	127.4	0.62	109.7	1.64	290.3	0.26	46.0
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.84	173.8	0.76	247.8	1.73	564.4	0.28	91.3
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	1.10	191.4	0.68	118.3	1.90	330.6	0.23	40.0
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	1.14	150.0	0.78	239.5	1.92	589.4	0.30	92.1
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.30	384.8	0.95	281.2	2.19	648.2	0.32	94.7
LSD at 5%	0.268	25.17	0.053	12.58	0.053	17.9	0.189	7.7

RDF=Recommended Doses of Fertilizer   PL= Poultry Litter   Conc. = Concentration

Table 6.9 Effects of NPK fertilizers and poultry litter on the concentration and uptake of NPKS in seed

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
PL_1:Control	2.89	213.9	0.26	19.2	0.44	32.6	0.15	11.1
PL_2: 1.5t PL ha^{-1} (50 % RDF)	3.89	462.9	0.36	42.8	0.61	72.6	0.16	19.0
PL_3: 3t PL ha^{-1} (100 % RDF)	4.10	516.6	0.34	42.8	0.66	83.2	0.17	21.4
PL_4: 4.5t PL ha^{-1} (150 % RDF)	4.41	564.5	0.38	48.6	0.71	90.9	0.17	21.8
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	3.18	572.4	0.54	97.2	0.72	129.6	0.13	23.4
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	3.19	685.9	0.56	120.4	0.77	165.6	0.15	32.3
PL_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	3.20	1110.9	0.59	204.7	0.76	263.7	0.18	62.5
PL_8: 1.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	4.39	1137.0	0.56	145.0	0.77	299.4	0.20	51.8
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	4.84	1655.3	0.57	194.9	0.81	277.0	0.22	75.2
PL_{10}:1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	5.14	1747.6	0.68	231.2	0.84	285.6	0.14	44.2
PL_{11}: 3t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.63	1861.3	0.56	225.1	0.87	349.7	0.22	88.4
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	5.11	1849.8	0.75	271.5	0.90	325.8	0.31	112.2
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	5.18	2294.7	0.86	381.0	1.01	447.4	0.29	128.5
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	5.01	2224.4	0.76	337.4	0.88	390.7	0.22	97.7
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	5.06	1831.7	0.79	282.4	0.94	340.3	0.21	76.0
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.83	1729.1	0.79	268.5	1.02	365.2	0.20	71.6
LSD at 5%	0.18	74.28	0.139	41.17	0.04	32.91	0.04	14.4

RDF=Recommended Doses of Fertilizer PL= Poultry Litter Conc. = Concentration

6.3.4 Effects of NKP fertilizers and poultry litter on the oil and protein contents of sunflower seed

6.3.4.1 Oil content

Per cent oil content in sunflower seeds varied significantly ($P < 0.05$) over the control due to application of various combinations of poultry litter and fertilizers (Table 6.10).

The highest yield of oil content (47.7%) and the lowest oil content (37.7%) were found in 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 4.5t PL+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments respectively. Among the treatments, the significant variation was found to in some cases. The treatments, where the highest amount poultry litter and NPK fertilizers were added showed the lowest per cent of oil content (Table 6.10).

6.3.4.2 Protein content

Percent protein content showed very similar trend as in case of per cent oil in sunflower seed's due to application of various combinations of poultry litter and NPK fertilizers (Table 6.10).

Among the various combinations of poultry litter and NPK fertilizers, the best yield of protein (31.8%) was obtained with the application of 3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Control treatment showed the lowest yield of protein (18.0%). Results further showed that variations among the treatments were found to be not significant in most of the cases (Table 6.10). Percent protein content increased with the increase of poultry litter and NPK fertilizers.

Table 6.10 Effects of NPK fertilizers and poultry litter on the oil and protein contents of sunflower seeds

Treatments	% oil content	% protein content
PL_1: Control	42.6	18.0
PL_2: 1.5t PL ha^{-1} (50 % RDF)	43.1	23.8
PL_3: 3t PL ha^{-1} (100 % RDF)	44.0	25.4
PL_4: 4.5t PL ha^{-1} (150 % RDF)	44.2	27.1
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	38.5	20.3
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	43.3	20.4
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	40.7	20.4
PL_8: 1.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	42.2	27.5
PL_9: 1.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	43.2	30.0
PL_{10}: 1.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	46.0	31.5
PL_{11}: 3t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	41.8	28.7
PL_{12}: 3t PL ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	47.7	31.5
PL_{13}: 3t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	46.2	31.8
PL_{14}: 4.5t PL ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	44.0	30.8
PL_{15}: 4.5t PL ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	43.7	31.3
PL_{16}: 4.5t PL ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	37.7	30.4
LSD at 5%	1.6	0.08

RDF= Recommended dose of fertilizer PL = poultry litter

6.3.5 Effects of NKP fertilizers and poultry litter on the benefit: cost ratios of sunflower

Variable benefit: cost ratios were observed among the treatments. Economic analysis of the yield of percent oil showed an appreciable variation among the treatments (Table 6.11)

Benefit: cost ratios were recorded to be higher in the treatments of poultry litter and NPK fertilizers over the control. The highest and the lowest values of benefit: cost ratios were observed to be 2.58 and 1.00 in 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and control treatments, respectively. The second highest value (2.52) was recorded in the treatment, 3t PL ha^{-1}+$N_{40}P_{30}K_{60}$kg ha^{-1}.

Table 6.11 Effects of NPK fertilizers and poultry litter on the benefit: cost ratio of sunflower

Treatments	Cost of cultivation (Tk. ha^{-1})	Gross returns (Tk. ha^{-1})	Net returns (Tk. ha^{-1})	Benefit: Cost ratios
PL_1: Control	14120.00	14100.00	-20.00	1.00
PL_2: 1.5t PL ha^{-1} (50 % RDF)	17300.00	22800.00	5500.00	1.32
PL_3: 3t PL ha^{-1} (100 % RDF)	21210.00	24300.00	3090.00	1.15
PL_4: 4.5t PL ha^{-1} (150 % RDF)	24645.00	24600.00	-45.00	1.00
PL_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	30760.00	34500.00	3740.00	1.12
PL_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	27750.00	41400.00	13950.00	1.49
PL_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	30120.00	66600.00	36480.00	2.21
PL_8:1.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	28030.00	49800.00	21770.00	1.78
PL_9: 1.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	30400.00	65700.00	35300.00	2.16
PL_{10}: 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	32770.00	65400.00	35000.00	2.00
PL_{11}: 3t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	30680.00	77400.00	46720.00	2.52
PL_{12}: 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	33050.00	69600.00	36550.00	2.11
PL_{13}:3t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	35420.00	85200.00	49780.00	2.41
PL_{14}: 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	33130.00	85500.00	52370.00	2.58
PL_{15}: 4.5t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	35500.00	69600.00	34100.00	1.96
PL_{16}: 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	37870.00	68700.00	30830.00	1.81

RDF= Recommended dose of fertilizer PL = poultry litter

6.4 Conclusion

From the above findings the following conclusions can be made

(i) 3t PL plus $N_{120}P_{90}K_{150}$kg ha^{-1} and 4.5t PL plus $N_{120}P_{90}K_{150}$kg ha^{-1} are the better doses for growth, yield and NPKS content in the root, stem, leaf, petiole, inflorescence and seeds of sunflower.

(ii) Oil content was found the highest in the treatment 3t PL plus $N_{80}P_{60}K_{100}$kg ha^{-1}.

(iii) Protein content was found highest in the treatment 3t PL plus $N_{120}P_{90}K_{150}$kg ha^{-1}.

(iv) According to benefit: cost ratios the best dose in 4.5t PL plus $N_{40}P_{30}K_{50}$kg ha^{-1} treatment.

Chapter 7

Assessment of NPK Fertilizers and Vermicompost on the Growth, Yield and Nutrient Content of Sunflower (*Helianthus annus* L.)

7.1 Introduction

Agricultural production of Bangladesh increased remarkably during twenty century as a result of "Green revolution". Bangladesh could achieve self-sufficiency in agriculture by an increased combination use of organic manure and chemical fertilizers. Agro-chemicals deteriorate soil health and environment was got polluted. Human beings and cattle were adversely affected due to the residues of these agro-chemicals in food products (Kumar and Singh, 2013). So, organic manures like vermicompost can be a good substitute for chemical fertilizers to overcome their adverse effects (Joshi *et al*., 2013). Vermicompost are effective organic fertilizers and bio-control agents (Edwards and Aracon, 2004; Joshi *et al*., 2013). Bangladesh farmers are using of numerous organic manures, especially vermicompost to protect environmental hazards and soil health. A little information is found in the literature on organic farming (Purna *et al.*, 2020). Vermicompost can improve food quality without compromising with food safety. Both developed and developing countries are using vermicomposting during last 40 years. There is the possibility of increasing the nitrogen content of compost by inoculation with nitrogen- fixing organisms, and the phosphorus content by the addition of rock phosphate and then inoculation with phosphate-solubilizing bacteria, since direct application of rock phosphate is not useful, particularly in neutral and alkaline soils (Premono *et al*., 1996). Composting organic refuse with rock phosphate and microbial activities may help to solubilize phosphorus and to increase phosphorus availability to plants. Nitrogen- fixing bacteria, besides fixing N, solubilize P due to production of organic acids and enzymes (Kumar and Narula, 1999).

The objectives of the experiment were to assess the effect of NPK fertilizers and vermicompost on the growth, yield and nutrient content of sunflower (*Helianthus annus* **L**.) at the research farm of Charfasson Govt. College, Bhola.

7.2 Materials and methods

7.2.1 Location, description and climatic condition

Geographic location, description and climatic condition of the experimental site are described in the sections 3.1 and 3.2; and Tables 3.1 and 3.3, respectively, in Chapter 3.

7.2.2 Collection of soil samples and analysis

7.2.2.1 Physical properties of soil

Soil sample collection and physical properties of soil, i.e. particle size, textural class, bulk density, particle density, maximum water retentive capacity are described in the sections 3.3, 3.3.1, 3.3.1.1, 3.3.1.2, 3.3.1.3, 3.3.1.4 and 3.3.1.5, respectively, and Table 3.4 in Chapter 3.

7.2.2.2 Chemical properties of soil

Soil chemical properties i.e. P^H, EC, OC, OM, total nitrogen, available nitrogen, available phosphorus, exchangeable potassium, available sulfur and heavy metal are described in the sections 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.2.4, 3.3.2.5, 3.3.2.6, 3.3.2.7, 3.3.2.8, 3.3.2.9 and 3.3.2.10, respectively, and Table 3.4 in Chapter 3.

7.2.3 Experimental

Preparation of vermicompost and its physical and chemical analysis are described in the sections 3.4, 3.4.1, 3.4.1.4 and 3.4.2, respectively, and Table 3.5 in Chapter 3.

7.2.3.1 Treatments of NPK fertilizers and vermicompost

VC_1: Control -(VC & NPK)
VC_2: 2.5 t ha^{-1} VC (50% RDF)
VC_3: 5t ha^{-1} VC (100% RDF)
VC_4: 7.5 t ha^{-1} VC (150% RDF)
VC_5: $N_{40}P_{30}K_{50}$ kg ha^{-1} (50% RDF)
VC_6: $N_{80}P_{60}K_{100}$ kg ha^{-1} (100% RDF)
VC_7: $N_{120}P_{90}K_{150}$ kg ha^{-1} (150% RDF)
VC_8: 2.5t ha^{-1} VC +$N_{40}P_{30}K_{50}$kg ha^{-1}
VC_9: 2.5t ha^{-1} VC +$N_{80}P_{60}K_{100}$kg ha^{-1}
VC_{10}: 2.5t ha^{-1} VC +$N_{120}P_{90}K_{150}$kg ha^{-1}
VC_{11}: 5t ha^{-1} VC+$N_{40}P_{30}K_{50}$ kg ha^{-1}
VC_{12}: 5t ha^{-1} VC+$N_{80}P_{60}K_{100}$kg ha^{-1}
VC_{13}: 5t ha^{-1} VC+$N_{120}P_{90}K_{150}$ kg ha^{-1}
VC_{14}: 7.5t ha^{-1} VC+$N_{40}P_{30}K_{40}$kg ha^{-1}
VC_{15}: 7.5t ha^{-1} VC+$N_{80}P_{60}K_{100}$ kg ha^{-1}
VC_{16}: 7.5t ha^{-1} VC+$N_{120}P_{90}K_{150}$ kg ha^{-1}

7.2.4 Crop husbandry

Design, land preparation, fertilizers application, sowing of seed, germination of seed, intercultural practices i.e. insects and diseases management, weeding, spading, thinning and vacancy supplying are described in the sections 3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.6.1 and 3.5.6.2, respectively, in Chapter 3.

7.2.5 Biometric observations

Biometric observations i.e. plant height (cm), number of leaves $plant^{-1}$, leaf area (cm^2), leaf area index (LAI), are described in the sections 3.6, 3.6.1, 3.6.2, 3.6.3 and 3.6.4, respectively, in Chapter 3.

7.2.6 Harvesting and yield components

Harvesting, head diameter (cm), threshing seed, yield components *viz.* number of seeds $plant^{-1}$, seed yield (g $plant^{-1}$), 100 seed weight (g) are described in the sections 3.7, 3.7.1, 3.7.2, 3.8, 3.8.1, 3.8.2 and 3.8.3, respectively, in Chapter 3.

7.2.7 Plant sample analysis

Digestion of plant samples for nitrogen concentration, digestion of plant samples (root, stem, leaf, petiole, inflorescence and seed) with conc. nitric perchloric acid mixture, determination of phosphorus, potassium, sulfur concentration, oil of seed and oil yield (g $plant^{-1}$), seed protein are described in the sections 3.9, 3.10, 3.10.1, 3.10.1.1, 3.10.1.2, 3.10.1.3, 3.11, 3.12, respectively, in Chapter 3.

7.2.8 Uptake of nutrient

Uptake of nutrients by different parts of sunflower plant is described in the section 3.13 in chapter 3.

7.2.9 Economic analysis

Economic analysis is described in the section 3.14 in Chapter 3.

7.2.10 Statistical analysis

Statistical analysis is described in the section 3.15 in Chapter 3.

7.3 Results and discussion

Effects of NPK fertilizers and vermicompost on the growth, yield, nutrient concentration and uptake, quality of seed and benefit: cost ratios of sunflower have been discussed in this section.

Vermicompost; 0.0, 2.5, 5.0, 7.5t ha^{-1} and NPK fertilizers; 0.0, 50, 100, 150% of recommended doses; alone and in combinations were applied.

7.3.1 Effects of NPK fertilizers and vermicompost on growth parameters of sunflower

Vermicompost, one of the potential source of organic fertilizer was used to examine its effect on growth of sunflower *viz.* height, leaf number, leaf area and leaf area index either alone (0.0, 2.5, 5.0, 7.5t ha^{-1}) or combination with NPK fertilizers (0.0, 50, 100, 150% RDF) in Tables 7.1-7.2.

7.3.1.1 Height (cm) and number of leaf (plant^{-1})

Results showed that treatments caused a significant and positive effect on the growth parameters i.e. height (cm) and number of leaf (plant^{-1}) of sunflower significantly ($P< 0.05$) as compared with the control during all the growth intervals *viz.* 30, 60, 90 days of sowing (Table 7.1). Combined application of vermicompost and NPK fertilizers produced better results than their individual applications. However, the variations among the treatments were not significant in most of the cases. The pattern of increase in height (cm) and number of leaf (plant^{-1}) increased with doses of both vermicompost and fertilizers.

Maximum height (cm) and leaf number (plant^{-1}) were recorded as, 198.4cm (7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}) and 45.3 plant^{-1} (7.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}), respectively, at the harvesting stage of the plant.

Between vermicompost and fertilizers, fertilizers alone showed better results than vermicompost in case of height and number of leaf. Generally, highest doses of both the vermicompost and fertilizers together produced comparatively higher results.

7.3.1.2 Leaf area (cm^2) and leaf area index

Results showed that treatments caused a significant and positive effect on the growth parameters i.e. leaf area (cm^2) and leaf area index of sunflower significantly ($P< 0.05$) as compared with the control during all the growth intervals *viz.* 30, 60, 90 days of sowing (Table 7.2). Combined application of vermicompost and NPK fertilizers produced better results than their individual applications. However, the variations among the treatments were not significant in most of the cases. The pattern of increase in height (cm) and number of leaf (plant^{-1}) increased with doses of both vermicompost and fertilizers.

Maximum leaf area (cm^2) and leaf area index were recorded as, 381.0cm^2 (7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}) and 14.62 (7.5t VC ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1}), respectively, at the harvesting stage of the plant. Minimum values were recorded in the control in all the cases of growth parameters (Table 7.2).

Table 7.1 Effects of NPK fertilizers and vermicompost on height (cm) and number of leaf ($plant^{-1}$)

Treatments	Days after sowing					
	Height (cm)			Number of leaf ($plant^{-1}$)		
	30	60	90	30	60	90
VC_1: Control	29.0	77.7	85.6	11.7	16.0	26.2
VC_2: 2.5t VC ha^{-1} (50 % RDF)	31.3	105.0	97.5	12.7	18.7	28.6
VC_3: 5t VC ha^{-1} (100 % RDF)	51.3	130.7	127.0	14.7	21.7	30.2
VC_4:7.5t VC ha^{-1} (150 % RDF)	63.7	139.7	139.0	15.7	24.7	35.1
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	59.0	127.7	144.5	18.0	21.0	36.5
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	58.0	138.3	177.0	14.0	23.0	37.2
VC_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	65.0	157.3	180.5	16.7	24.0	42.2
VC_8: 2.5t VC ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	67.7	145.3	168.5	17.0	21.0	39.5
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	60.3	162.3	176.6	16.7	26.7	41.2
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	76.0	178.0	185.3	19.3	23.7	41.3
VC_{11}: 5t VC ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	53.7	154.0	182.5	15.7	21.0	32.2
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	55.3	168.0	177.3	14.3	25.7	34.8
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	70.7	182.0	185.0	16.7	23.7	36.2
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	70.0	174.0	188.0	18.3	25.7	39.5
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	56.7	166.0	198.4	15.3	24.3	42.2
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	69.3	196.3	195.5	17.0	27.0	45.3
LSD at 5 %	16.69	13.8	5.09	2.74	3.13	4.58

RDF= Recommended dose of fertilizer VC= Vermicompost

Table 7.2 Effects of NPK fertilizers and vermicompost on leaf area (cm^2) and leaf area index

Treatments	Days after sowing					
	Leaf area			Leaf area index		
	30	60	90	30	60	90
VC_1: Control	69.0	39.0	112.5	0.81	0.63	2.52
VC_2: 2.5t VC ha^{-1} (50 % RDF)	80.4	96.0	120.2	1.02	1.80	2.86
VC_3: 5t VC ha^{-1} (100 % RDF)	130.3	76.0	140.8	1.92	1.65	4.25
VC_4:7.5t VC ha^{-1} (150 % RDF)	124.5	134.7	180.0	1.98	3.34	5.33
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	174.5	88.0	203.5	3.15	1.86	6.28
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	151.7	141.0	292.6	2.15	4.08	8.11
VC_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	179.5	148.7	255.2	3.02	3.53	8.92
VC_8: 2.5t VC ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	146.7	128.7	265.0	2.48	2.73	9.96
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	153.0	173.7	285.5	2.50	4.64	10.12
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	167.3	248.0	350.2	3.19	5.86	12.16
VC_{11}: 5t VC ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	120.0	113.3	330.5	2.04	2.39	8.05
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	150.8	165.7	344.5	2.16	4.27	9.35
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	169.3	212.7	348.6	2.78	4.94	10.85
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	188.8	156.7	340.7	3.47	4.02	11.32
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	136.0	180.7	381.0	2.07	4.41	13.56
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	242.7	258.7	370.4	4.13	7.02	14.62
LSD at 5 %	16.69	157.64	5.94	0.97	2.04	0.68

RDF= Recommended dose of fertilizer VC = Vermicompost

7.3.2 Effects of NPK fertilizers and vermicompost on dry matter and seed yield parameters of sunflower plant

The integrated effects of vermicompost and NPK fertilizers on the growth and yield of sunflower plant have been measured in this section (Table 7.3).

7.3.2.1 Dry weights of stem and root (g plant^{-1})

Dry weights of stem and root of sunflower plant showed significant response to application of vermicompost and fertilizers and the weights of both the parameters increased significantly ($P< 0.05$) over the control except in treatments of vermicompost where applied alone (Table 7.3).

The dry weights of both stem and root of sunflower plant increase with increasing rates of vermicompost and fertilizers in most of the cases though not significantly ($P< 0.05$). Effects of fertilizers were found to be better than vermicompost when applied alone in both of the cases. Combined application of vermicompost and fertilizers generally showed better effect to enhance the dry weights of stem and root than their individual application. Highest weights of stem (72.4g plant^{-1}) and root (18.87g plant^{-1}) were recorded in the same treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}, i.e. in highest dose of fertilizers. However, treatment of 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1} showed statistically identical result to $N_{120}P_{90}K_{150}$kg ha^{-1} treatment in case dry weight of sunflower root. Similarly, in case of dry weight of stem, the treatment which showed the highest dry weight was found to be identical to treatments, 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}.

7.3.2.2 Dry weights of leaf and petiole (g plant^{-1})

Changes in weights of leaf plant^{-1} and petiole plant^{-1} of sunflower plant showed all most similar pattern as in case of weights of root plant^{-1} and stem plant^{-1} due to addition of vermicompost and fertilizers either alone or in combinations (Table 7.3).

Changes in weights of leaf plant^{-1} and petiole plant^{-1} were positive and increased over the control significantly ($P< 0.05$) except the treatments where only vermicompost was applied. However, application of fertilizers alone and in combination with vermicompost increased the dry weights of both leaf and petiole plant^{-1} significantly ($P< 0.05$) though their variations among the treatments were found to be statistically identical.

The highest weights of leaf (19.2g plant^{-1}) and petiole (7.7g plant^{-1}) was recorded in treatments, 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Table 7.3 Effects of NPK fertilizers and vermicompost on dry matter and seed yield parameters of sunflower

Treatments	Root (g $plant^{-1}$)	Stem (g $plant^{-1}$)	Leaf (g $plant^{-1}$)	Petiole (g $plant^{-1}$)	Inflores-cence (g $plant^{-1}$)	Total dry matter yield (g $plant^{-1}$)	Total dry matter yield (t ha^{-1})	Diameter of inflores-cence (cm)	Wt. of seed (g $plant^{-1}$)	Number of seed $Plant^{-1}$	Wt. of 100 seed (g)
VC_1: Control	2.14	6.9	5.0	1.7	4.9	20.7	1.08	28.7	8.07	119.7	5.60
VC_2: 2.5t VC ha^{-1} VC (50 % RDF)	3.90	22.5	5.9	2.0	7.7	42.0	2.18	29.0	10.81	191.0	5.60
VC_3: 5t VC ha^{-1} (100 % RDF)	3.88	21.7	7.2	2.4	7.3	42.3	2.20	35.3	16.11	309.0	6.13
VC_4: 7.5t VC ha^{-1} (150 % RDF)	5.19	30.7	8.6	3.0	8.8	56.3	2.92	37.3	16.44	280.7	5.83
VC_5:$N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF).	4.43	24.8	6.0	2.8	10.6	48.6	2.52	37.7	18.95	382.3	5.97
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1}.(100% RDF)	10.11	46.4	16.9	4.8	20.4	98.6	5.12	49.0	28.71	468.7	6.73
VC_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF).	18.87	72.4	16.7	7.6	38.3	153.9	7.99	59.7	29.44	542.0	6.27
VC_8: 2.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	5.81	29.4	6.7	3.7	26.7	72.3	3.75	47.3	28.98	516.3	6.37
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	10.63	36.8	7.4	4.2	22.0	81.1	4.21	47.3	32.39	521.0	6.77
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}.	15.89	64.0	19.2	6.2	19.0	124.2	6.45	54.3	44.27	631.0	7.10
VC_{11}: 5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	3.74	18.7	6.9	2.9	13.3	45.5	2.36	39.3	38.65	476.7	6.53
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	8.91	35.6	10.5	4.4	24.8	84.2	4.37	47.0	57.61	603.7	7.07
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	10.83	50.2	15.5	7.7	36.6	120.8	6.27	62.3	55.44	676.7	6.77
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	9.66	40.2	8.9	3.9	27.2	89.8	4.66	47.7	45.94	625.3	7.0
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	13.66	59.5	12.0	4.9	28.4	118.5	6.15	50.7	47.54	636.7	7.07
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	12.60	54.8	16.1	7.2	30.7	121.3	6.30	60.0	36.14	496.7	7.53
LSD at 5 %.	4.72	18.97	6.49	1.89	6.65	15.51	0.44	15.92	16.65	238.82	1.07

RDF=Recommended Dose of Fertilizer VC = Vermicompost

7.3.2.3 Dry weight of inflorescence (g plant^{-1})

Behaviors of treatment combinations of vermicompost and fertilizers on dry weight of inflorescence was very much similar to dry weights of root, stem, leaf and petiole plant^{-1} (Table 7.3).

Increase in dry weight of inflorescence increased with the rate of vermicompost and fertilizers in all combinations of treatments over the control significantly ($P< 0.05$). Vermicompost alone was found to be not effective to increase the dry weight of inflorescence plant^{-1} significantly ($P< 0.05$). The variation in changes in dry weight of inflorescence was again recorded to be statistically identical in most of the cases. The highest dry weight of inflorescence was 38.3g plant^{-1} recorded in treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}.

7.3.2.4 Total dry matter yield (g plant^{-1}) and (t ha^{-1})

Total dry matter plant^{-1} of sunflower plant increased markedly over the control due to application of vermicompost and fertilizers applied in various combinations (Table 7.3). Dry matter production increased with increasing rates of both vermicompost and fertilizers. Variation in dry matters plant^{-1} among the treatments was also noticeable. The highest dry matter production (153.9g plant^{-1}) or (7.99t ha^{-1}) was recorded in the treatment, $N_{120}P_{90}K_{150}$kg ha^{-1}. Yield of dry matter in tones ha^{-1} also followed the same trend as in dry matter yield plant^{-1}, which is quite obvious.

7.3.2.5 Diameter of inflorescence (cm)

Diameter of inflorescence of sunflower plant showed an increase in with the increase in rate of vermicompost and fertilizers significantly ($P< 0.05$) over the control (Table 7.3). Variation in diameter, however, among the treatments, in most of the cases was not statistically significant. The highest diameter (62.3cm) of inflorescence was observed in the treatment, 5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

7.3.2.6 Weight of seeds (g plant^{-1}) and number of seeds (plant^{-1})

Weight of seed plant^{-1} and number of seeds plant^{-1} increased significantly ($P< 0.05$) over the control due to application of various treatments of vermicompost and fertilizers (Table 7.3). Yield of seed plant^{-1} and number of seeds plant^{-1} increased with the increasing rates of both vermicompost and NPK fertilizers. However, the variation in both the yield parameters among the treatments was found to be statistically identical in most of the cases. The yield of seed plant^{-1} (57.61g) and number of seed plant^{-1} (676.7) were found to be maximum in the treatments, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

7.3.2.7 Weight of 100 seed grains (g)

Vermicompost and fertilizers applied to sunflower produced a positive effect on weight of 100 grains and was found to be significant only in 50% of the treatments as compared to control (Table 7.3). The increase in weight of 100 grains was found to be irregular with rates of both vermicompost and fertilizers. The best weight of 100 grains of sunflower was recorded as 7.53g and was found in 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment.

7.3.3 Nutrient concentration and uptake of different organs of sunflower plant

Vermicompost (0.0, 2.5, 5.0, 7.5t ha^{-1}) and NPK fertilizers (00, 50, 100, 150% RDF) in various combinations were applied on sunflower grown in the field. Concentrations of nitrogen, phosphorus, potassium and sulfur in different parts of the plant were measured (Tables 7.4-7.9).

Results showed that vermicompost and NPK fertilizers influenced the concentration of nutrients in the similar way as CD, RB and PL. The pattern of change in concentration of nitrogen, phosphorus, potassium and sulfur due to treatments was significant ($P< 0.05$) over the control in all the organic parameters of the plant. However, the variations between the treatments were found to be identical in most of the cases irrespective of the source of nutrients and agronomic parameters.

7.3.3.1 Concentration and uptake of NPKS in stem

Concentrations of nutrients increased with doses of both vermicompost and NPK fertilizers in most of the treatments. Uptake of the nutrients showed the reflection of dry weight of the respective parameters (Tables 7.3-7.4).

Concentration and uptake of nitrogen and phosphorus in stem of sunflower plant ranged from 0.22 to 0.42 and 0.05 to 0.23%, and 15.2 to 304.1 and 3.50 to 115.8 mg plant^{-1} stem respectively (Table 7.4).

The highest values of the nutrients (nitrogen and phosphorus) were observed in treatments, $N_{120}P_{90}K_{150}$kg ha^{-1}, 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}; and 5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and $N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

Concentration and uptake of potassium and sulfur varied from 0.72 to 1.95 and 0.03 to 0.12%, and 49.7 to 999.6 and 2.1 to 76.8 mg $plant^{-1}$ stem respectively. The highest values were recorded in 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}, 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}; and 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 2.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively.

7.3.3.2 Concentration and uptake of NPKS in root

Concentration and uptake of nitrogen and phosphorus in root of sunflower plant ranged from 0.32 to 0.57 and 0.13 to 0.33%, and 6.8 to 84.9 and 2.8 to 41.6 mg $plant^{-1}$ root respectively (Table 7.5).

The highest values were observed in 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments, and $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1} treatments respectively. Concentration and uptake of potassium and sulfur ranged from 0.54 to 2.66 and 0.07 to 0.20%, and 11.6 to 341.8 and 1.5 to 23.8 mg $plant^{-1}$ root respectively (Table 7.5).

Maximum values of potassium and sulfur concentration were observed in the same treatment, 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Highest values of potassium and sulfur uptake were recorded in 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} treatments respectively. Uptake of the nutrients showed the reflection of dry weight of root (Tables 7.3 and 7.5).

Table 7.4 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in stem

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
VC_1: Control	0.22	15.2	0.05	3.50	0.72	49.7	0.03	2.1
VC_2: 2.5t VC ha^{-1} (50 % RDF)	0.26	58.5	0.08	18.0	0.80	180.0	0.05	11.3
VC_3: 5t VC ha^{-1} (100 % RDF)	0.27	58.6	0.11	23.9	0.98	212.7	0.07	15.2
VC_4: 7.5t VC ha^{-1} (150 % RDF)	0.32	98.2	0.12	36.8	1.24	380.7	0.10	30.7
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.36	89.3	0.12	29.8	1.30	322.4	0.05	12.4
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.37	171.7	0.15	69.6	1.50	696.0	0.06	27.8
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.42	304.1	0.16	115.8	1.38	999.1	0.08	59.9
VC_8: 2.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	0.38	111.7	0.14	41.2	1.55	455.7	0.09	26.5
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.37	136.2	0.13	47.8	1.60	588.8	0.11	40.5
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.38	242.2	0.18	115.2	1.56	998.4	0.12	76.8
VC_{11}: 5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.34	63.6	0.17	31.8	1.70	317.9	0.10	18.7
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.37	131.7	0.16	57.0	1.85	658.6	0.11	39.2
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.40	200.8	0.23	115.5	1.95	978.9	0.12	60.2
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.27	108.5	0.19	76.4	1.80	723.6	0.10	40.2
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.36	214.2	0.17	101.2	1.68	999.6	0.11	65.5
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.42	230.2	0.16	87.7	1.82	997.4	0.12	65.8
LSD at 5%	0.04	27.11	0.053	8.51	0.24	84.12	0.053	5.97

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc. = Concentration

Table 7.5 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in root

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
VC_1: Control	0.32	6.8	0.13	2.8	0.54	11.6	0.07	1.5
VC_2: 2.5t VC ha^{-1} (50 % RDF)	0.33	12.9	0.14	5.8	0.75	29.3	0.10	3.9
VC_3: 5t VC ha^{-1} (100 % RDF)	0.34	13.2	0.16	6.2	0.89	34.5	0.12	4.7
VC_4: 7.5t VC ha^{-1} (150 % RDF)	0.37	19.2	0.16	8.3	1.03	53.5	0.13	6.7
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.44	19.4	0.16	7.1	1.08	47.8	0.08	3.5
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.40	40.4	0.15	15.2	1.18	119.3	0.09	9.1
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.45	84.9	0.17	32.1	1.31	247.2	0.07	13.2
VC_8: 2.5t VC ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.41	23.8	0.18	10.5	1.23	71.5	0.12	7.0
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.42	44.6	0.18	19.1	1.39	147.8	0.13	13.8
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.46	73.1	0.18	28.6	1.59	252.7	0.15	23.8
VC_{11}: 5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.38	14.2	0.20	7.5	1.77	66.2	0.14	5.2
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.43	38.3	0.23	20.5	2.02	180.0	0.17	15.1
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.57	61.7	0.32	34.7	2.66	288.1	0.20	21.7
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.33	31.9	0.22	21.3	2.42	233.8	0.11	10.6
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.42	57.4	0.24	32.8	2.50	341.8	0.14	19.1
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.46	58.0	0.33	41.6	2.34	294.8	0.16	20.2
LSD at 5%	0.04	4.14	0.04	4.01	0.34	16.14	0.053	4.28

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc. = Concentration

7.3.3.3 Concentration and uptake of NPKS in leaf

Values of concentration and uptake of nitrogen and phosphorus in leaf of sunflower plant ranged from 1.87 to 2.61 and 0.12 to 0.42%, and 93.5 to 476.2 and 6.0 to 65.1 mg plant^{-1} leaf respectively (Table 7.6).

The highest values of nitrogen and phosphorus concentration and uptake were recorded in 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment, and 2.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments, for their uptake.

Concentration and uptake of potassium and sulfur in leaf of sunflower varied from 0.84 to 2.77 and 0.06 to 0.19%, and 42.0 to 446.0 and 3.0 to 30.6 mg plant^{-1} leaf, respectively (Table 7.6). The highest values for both concentration and uptake of potassium and sulfur were observed in the same treatment, 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} where the highest amounts of vermicompost and NPK fertilizers added.

7.3.3.4 Concentration and uptake of NPKS in petiole

Concentration and uptake of nitrogen and phosphorus in petiole of sunflower ranged from 0.39 to 2.30 and 0.09 to 0.65%, and 6.6 to 165.6 and 1.5 to 46.8 mg plant^{-1} petiole respectively (Table 7.7).

Concentration and uptake of potassium and sulfur in petiole varied from 0.83 to 2.65 and 0.06 to 0.20%, and 14.1 to 190.8 and 1.0 to 15.4 mg plant^{-1} petiole respectively (Table 7.7). The maximum values of nitrogen, phosphorus and potassium (NPK) for both concentration and uptake in petiole were recorded in the same treatment, 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}. Treatment of 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1} showed the highest concentration and uptake of sulfur in the petiole of the same treatment.

Table 7.6 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in leaf

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
VC_1: Control	1.87	93.5	0.12	6.0	0.84	42.0	0.06	3.0
VC_2: 2.5t VC ha^{-1} (50 % RDF)	1.88	110.9	0.17	10.0	1.14	67.3	0.08	4.7
VC_3-5t VC ha^{-1} (100 % RDF)	1.89	136.1	0.18	13.0	1.25	90.0	0.09	6.5
VC_4: 7.5t VC ha^{-1} (150 % RDF)	1.96	168.6	0.20	17.2	1.54	132.4	0.11	9.5
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	2.00	120.0	0.20	12.0	1.75	105.0	0.07	4.2
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	2.04	344.8	0.22	37.2	1.78	300.8	0.06	10.1
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	2.06	344.0	0.26	43.4	1.87	312.3	0.07	11.7
VC_8: 2.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	2.10	140.7	0.23	16.1	1.88	126.0	0.11	7.4
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	2.14	158.4	0.24	17.8	1.94	143.7	0.13	9.6
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.48	476.2	0.32	61.4	2.06	395.5	0.15	28.8
VC_{11}: 5t VC ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	2.42	167.0	0.30	20.7	2.21	152.5	0.12	8.3
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	2.53	265.7	0.33	34.7	2.33	244.7	0.14	14.7
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.61	404.6	0.42	65.1	2.72	421.6	0.16	24.8
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	2.10	186.9	0.36	32.0	2.53	225.2	0.13	11.6
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	2.53	303.6	0.38	45.6	2.61	313.2	0.17	20.4
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.34	376.7	0.38	61.2	2.77	446.0	0.19	30.6
LSD at 5%	0.16	30.35	0.053	4.92	0.06	20.91	0.053	2.77

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc. = Concentration

Table 7.7 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in petiole

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})	Conc. (%)	Uptake (mg plant^{-1})
VC_1: Control	0.39	6.6	0.09	1.5	0.83	14.1	0.06	1.0
VC_2: 2.5t VC ha^{-1} (50 % RDF)	0.44	8.8	0.14	2.8	0.87	17.4	0.09	1.8
VC_3:5t VC ha^{-1} (100 % RDF)	0.46	11.0	0.17	4.1	0.91	21.8	0.10	2.4
VC_4:7.5t VC ha^{-1} (150 % RDF)	0.47	14.1	0.24	7.2	0.97	29.1	0.13	3.9
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.91	25.5	0.27	7.6	1.40	39.2	0.07	2.0
VC_6:$N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	0.82	39.4	0.28	13.4	1.56	74.9	0.08	3.8
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.93	70.7	0.29	22.0	1.71	130.0	0.09	6.8
VC_8: 2.5t VC ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	0.88	32.6	0.34	12.6	1.51	55.9	0.15	5.6
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}.	1.10	46.2	0.36	15.1	1.57	65.9	0.17	7.1
VC_{10}:2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.07	66.3	0.44	27.3	1.63	101.1	0.17	10.5
VC_{11}: 5t VC ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}	1.11	32.2	0.41	11.9	1.69	49.0	0.16	4.6
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	1.18	51.9	0.42	18.5	1.75	77.0	0.18	7.9
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	1.46	112.4	0.57	43.9	2.20	169.4	0.20	15.4
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	1.49	58.1	0.39	15.2	2.00	78.0	0.14	5.5
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	2.00	98.2	0.55	27.0	2.40	117.6	0.17	8.3
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	2.30	165.6	0.65	46.8	2.65	190.8	0.19	13.7
LSD at 5%	0.43	10.05	0.22	3.63	0.16	9.92	0.053	2.09

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc.= Concentration

7.3.3.5 Concentration and uptake of NPKS in inflorescence

Inflorescence of sunflower showed variable concentration of nitrogen, phosphorus, potassium and sulfur (NPKS) (Table 7.8).

Concentration and uptake of nitrogen and phosphorus varied from 0.22 to 0.76 and 0.10 to 0.71% and 9.8 to 278.2 and 4.9 to 218.0 mg plant^{-1} inflorescence of sunflower respectively (Table 7.8).

Concentration and uptake of potassium and sulfur ranged from 0.59 to 2.21 and 0.06 to 0.26%, and 28.9 to 678.5 and 2.9 to 80.5 mg plant^{-1} inflorescence respectively (Table 7.8). Treatment, 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, showed the highest concentration and uptake of nitrogen and uptake of sulfur. However, the highest values of concentration and uptake of rest of the nutrients were observed in the same treatment, 7.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}.

7.3.3.6 Concentration and uptake of NPKS in seed

Seed of sunflower also showed variable range of nitrogen, phosphorus, potassium and sulfur (Table 7.9).

Concentration and uptake of nitrogen and phosphorus ranged from 2.80 to 4.86 and 0.33 to 0.69%, and 226.0 to 2655.8 and 26.6 to 382.5 mg plant^{-1} seed respectively. The highest values of concentration of nitrogen was recorded in 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and that of phosphorus in 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 7.5t VC ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments, and uptake of nitrogen and phosphorus in 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments respectively.

Similarly, concentration and uptake of potassium and sulfur varied from 0.56 to 1.08 and 0.10 to 0.16%, and 42.2 to 571.0 and 8.1 to 92.2 mg plant^{-1} seed respectively (Table 7.9). The highest values for concentration and uptake of potassium were observed in 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatments, respectively. However, the same treatment, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} showed that maximum concentration and uptake of sulfur in sunflower seed.

Table 7.8 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in inflorescence

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
VC_1:Control	0.22	9.8	0.10	4.9	0.59	28.9	0.06	2.9
VC_2: 2.5t VC ha^{-1} (50 % RDF)	0.24	18.5	0.14	10.8	0.74	57.0	0.12	9.2
VC_3: 5t VC ha^{-1} (100 % RDF)	0.27	19.7	0.16	11.7	0.81	59.1	0.15	11.0
VC_4: 7.5t VC ha^{-1} (150 % RDF)	0.40	35.2	0.19	16.8	0.92	81.1	0.17	15.0
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	0.45	47.7	0.25	26.5	1.10	116.6	0.06	6.4
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF).	0.49	100.0	0.27	55.1	1.38	281.5	0.09	18.4
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	0.42	160.9	0.34	130.2	1.50	574.5	0.10	38.3
VC_8: 2.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	0.44	117.5	0.37	98.8	1.43	381.3	0.13	34.7
VC_9:2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.63	138.6	0.39	85.8	1.53	336.6	0.16	35.2
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.67	127.3	0.44	83.6	1.55	294.5	0.18	34.2
VC_{11}: 5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.61	81.1	0.42	55.9	1.52	202.2	0.22	29.3
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	0.68	168.6	0.45	111.6	1.57	389.4	0.21	52.1
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.76	278.2	0.49	179.3	1.81	662.5	0.22	80.5
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	0.70	190.4	0.46	125.1	1.77	481.4	0.24	65.3
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	0.72	204.5	0.55	156.2	1.95	553.8	0.25	71.0
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	0.68	208.8	0.71	218.0	2.21	678.5	0.26	79.8
LSD at 5%	0.053	12.35	0.189	8.57	0.106	26.92	0.427	6.9

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc. = Concentration

Table 7.9 Effects of NPK fertilizers and vermicompost on the concentration and uptake of NPKS in seed

Treatments	Nitrogen		Phosphorus		Potassium		Sulfur	
	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)	Conc. (%)	Uptake (mg $plant^{-1}$)
VC_1: Control	2.80	226.0	0.33	26.6	0.56	42.2	0.10	8.1
VC_2: 2.5t VC ha^{-1} (50 % RDF)	3.03	327.5	0.38	41.1	0.64	69.2	0.12	13.0
VC_3: 5t VC ha^{-1} (100 % RDF)	3.48	560.6	0.34	54.8	0.74	119.2	0.14	22.6
VC_4: 7.5t VC ha^{-1} (150 % RDF)	3.57	586.9	0.40	65.8	0.79	129.9	0.15	24.7
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	3.24	614.0	0.45	85.3	0.83	157.3	0.14	26.5
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	4.27	1225.9	0.48	137.8	0.81	232.6	0.14	40.2
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	4.46	1313.0	0.51	150.1	0.82	241.4	0.15	44.2
VC_8: 2.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$ kg ha^{-1}	2.99	866.5	0.44	127.5	0.85	246.3	0.13	37.7
VC_9: 2.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	3.97	1285.9	0.54	174.9	0.85	275.3	0.14	45.3
VC_{10}: 2.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.86	2151.5	0.61	270.0	0.84	371.9	0.14	62.0
VC_{11}: 5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	4.28	1654.2	0.60	231.9	0.87	336.3	0.15	58.0
VC_{12}: 5t VC ha^{-1} + $N_{80}P_{60}K_{100}$ kg ha^{-1}	4.61	2655.8	0.61	351.4	0.95	547.3	0.16	92.2
VC_{13}: 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.45	2467.1	0.69	382.5	1.03	571.0	0.15	83.2
VC_{14}: 7.5t VC ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}	3.88	1782.5	0.66	303.2	0.96	441.0	0.14	64.3
VC_{15}: 7.5t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1}	4.57	2172.6	0.69	328.0	1.08	513.4	0.14	66.6
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	4.81	1738.3	0.69	249.4	1.04	375.9	0.15	54.2
LSD at 5%	0.30	63.58	0.105	29.09	0.04	23.67	0.024	10.41

RDF=Recommended Doses of Fertilizer VC= Vermicompost Conc. = Concentration

7.3.4 Effects of NKP fertilizers and vermicompost on the oil and protein contents of sunflower seeds.

7.3.4.1 Oil content

Percent oil content of sunflower seed showed a wide variation among the treatments of vermicompost and NPK fertilizers (Table 7.10).

The treatments showed a decrease in percent oil content in all the treatments significantly ($P< 0.05$) when compared with the control except the treatments of 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}, 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. The maximum and minimum values of per cent oil contents ranged from 46.9 to 29.7% recorded in 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and $N_{120}P_{90}K_{150}$kg ha^{-1} treatments, respectively, which was the highest dose of RDF NPK fertilizers (Table 7.10).

7.3.4.2 Protein content

Application of vermicompost and fertilizers on per cent protein content of sunflower seeds showed significant variation over the control (Table 7.10). The variation in per cent protein content was found to be significant ($P< 0.05$) when compared with the control in most of the cases. The maximum and the minimum values of percent protein were found in the treatments of 5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1} and control and the values ranged from 31.0 to 17.4% respectively.

Table 7.10 Effects of NPK fertilizers and vermicompost on the oil and protein contents of sunflower seeds

Treatments	% oil content	% protein content
VC_1: Control	41.9	17.4
VC_2: 2.5t VC ha^{-1} (50 % RDF)	33.9	19.4
VC_3: 5t VC ha^{-1} (100 % RDF)	34.9	21.6
VC_4: 7.5t VC ha^{-1} (150 % RDF)	36.9	22.2
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	30.6	20.1
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	35.1	26.5
VC_7:$N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	29.7	27.8
VC_8: 2.5t VC ha^{-1}+$N_{40}P_{30}K_{50}$ kg ha^{-1}	44.8	19.2
VC_9: 2.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	33.1	24.7
VC_{10}: 2.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	45.9	30.5
VC_{11}: 5t VC ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	32.0	26.9
VC_{12}: 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$ kg ha^{-1}	45.3	28.7
VC_{13}: 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	46.7	31.0
VC_{14}: 7.5t VC ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	37.9	26.3
VC_{15}: 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}	46.9	28.5
VC_{16}: 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}	43.8	29.1
LSD at 5%	3.99	2.01

RDF= Recommended dose of fertilizer VC= Vermicompost

7.3.5 Effects of NKP fertilizers and vermicompost on the benefit: cost ratio of sunflower

Calculated benefit: cost ratios of sunflower seed ranged from 1.06 to 3.35% recorded in control and 3t VC ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1} treatments respectively (Table 7.11).

Variable benefit: cost ratios were observed among the treatments. Maximum benefit: cost ratio (3.35) was found in the treatment, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} which is produced 45.3% oil.

Table 7.11 Effects of NPK fertilizers and vermicompost on the benefit: cost ratio of sunflower

Treatments	Cost of cultivation (Tk. ha^{-1})	Gross returns (Tk. ha^{-1})	Net returns (Tk. ha^{-1})	Benefit : Cost ratio
VC_1: Control	14650.00	15600.00	950.00	1.06
VC_2: 2.5t VC ha^{-1} (50 % RDF)	18150.00	20700.00	2550.00	1.14
VC_3: 5t VC ha^{-1} (100 % RDF)	21625.00	30900.00	9250.00	1.43
VC_4: 7.5t VC ha^{-1} (150 % RDF)	25510.00	31500.00	5990.00	1.23
VC_5: $N_{40}P_{30}K_{50}$kg ha^{-1} (50% RDF)	24680.00	36300.00	11620.00	1.47
VC_6: $N_{80}P_{60}K_{100}$kg ha^{-1} (100% RDF)	27050.00	55200.00	28150.00	2.04
VC_7: $N_{120}P_{90}K_{150}$kg ha^{-1} (150% RDF)	29420.00	56700.00	27280.00	1.93
VC_8: 2.5t VC ha^{-1} +$N_{40}P_{30}K_{50}$ kg ha^{-1}	27680.00	55800.00	28120.00	2.02
VC_9: 2.5t VC ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1}	30050.00	62400.00	32350.00	2.08
VC_{10}: 2.5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}	32420.00	85200.00	52780.00	2.63
VC_{11}: 5t VC ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}	30680.00	74400.00	43720.00	2.43
VC_{12}: 5t VC ha^{-1}+ $N_{80}P_{60}K_{100}$ kg ha^{-1}	33050.00	110700.00	77650.00	3.35
VC_{13}: 5t VC ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}	35420.00	106800.00	71380.00	3.02
VC_{14}: 7.5t VC ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1}	33680.00	88200.00	54520.00	2.62
VC_{15}: 7.5t VC ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1}	36050.00	91500.00	55450.00	2.54
VC_{16}: 7.5t VC ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1}	38420.00	69600.00	31180.00	1.81

RDF= Recommended dose of fertilizer VC= Vermicompost

7.4 Conclusion

From the above findings the following conclusions made

(i) 5t VC plus $N_{120}P_{90}K_{150}$kg ha^{-1} was the best dose for growth, yield and NPKS content in the root, stem, leaf, petiole, inflorescence and seeds of sunflower.

(ii) Oil content (46.9) was found the highest in the treatment of 7.5t VC plus $N_{80}P_{60}K_{100}$kg ha^{-1}.

(iii) Protein content (31.0) was found the highest in the treatment of 5t VC plus $N_{120}P_{90}K_{150}$kg ha^{-1}.

(iv) According to the benefit: cost ratios the best doses in the treatment of 5t VC plus $N_{80}P_{60}K_{100}$kg ha^{-1} which is the recommended doses of both organic and inorganic fertilizers, Fertilizer Recommendation Guide (FRG, 2012) of Bangladesh Agriculture Research Council (BARC).

Chapter 8

General Discussion

The results of the experiments have critically discussed in the following sections.

8.1 Effects of NPK fertilizers and organic manures on growth and yield of sunflower

8.1.1 Effects of NPK and cow dung

Results showed that the highest plant height (204.8cm), number of leaf (41.2 plant^{-1}), leaf area (410.5cm^2) and leaf area index (12.75) were found in the integrated treatments of 7.5t CD ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}, 2.5t CD ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1} and 7.5t CD ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}, respectively, at maturity of sunflower and were statistically significant at 5% level (Tables 4.1-4.2).

These observations are in agreement with the finding of other workers. Shoghi-Kalkhoran *et al.* (2013) observed that the integrated application of organic and inorganic fertilizers significantly (P<0.05%) increased the leaf area index, plant height of sunflower in comparison to organic or chemical fertilizers applied alone. Agele and Taiwo (2013) showed that cow dung manures enhanced sunflower growth in terms of plant height, leaf area, number of leaves and leaf area index the over control significantly. Lukman *et al*. (2016) reported that complementary application of cow dung and NPK fertilizers significantly (P< 0.05) increased the height, number of leaves per plant, number of tillers per square meter of rice plant. The author further reported that complementary application of cow dung and NPK fertilizers significantly (P<0.05%) increased the grain yield and number of panicles per plant except thousand grain weight of rice as compared to control. Filho *et al.* (2013) reported that the sunflower plant cultivated in Haplic Luvisol with the highest dose of cattle manure (20% v/v) had a better performance over the control. Omogoye and Adewale (2015) also found that the combined application of cow dung and NPK (20-10-10kg ha^{-1}) significantly improved the growth i.e. plant height, stem girth over the control. Naing *et al.* (2010) reported that the combination of FYM and inorganic fertilizers increased significantly (P<0.05) LAI, tiller and panicle number per hill of rice over the control. Shahariar *et al.* (2013) reported that, apart from rice, both digested PL and CD bio-slurry had a significant positive effect (P < 0.01) on the growth and yield components of cabbage.

Results showed that higher dry weight of root (12.83g plant^{-1}) was found in the treatment, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. The highest dry weight of stem (60.67g plant^{-1}), petiole of leaf (10.0g plant^{-1}), inflorescence (19.33g plant^{-1}) and finally dry matter yield (121.34g plant^{-1}) or (6.3t ha^{-1}) were found in the treatment, 7.5t CD ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.3). However, the highest dry weight of leaf (25.33g plant^{-1}) was found in the treatment, 7.5t CD ha^{-1} + $N_{40}P_{30}K_{50}$kg ha^{-1}. The highest diameter of inflorescence (52.67cm plant^{-1}) was found in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 4.3). The values of all growth and dry matter yield parameters were found significantly (P< 0.05) higher than in the combined treatment of organic manure and NPK fertilizers.

These findings are in consent with Akbari *et al.* (2011) who reported that maximum biological yields of sunflower were obtained with 50% farm yard manure and 50% N and was significantly higher than control. Shoghi-Kalkhoran *et al.* (2013) cited that the integrated combination of fertilizers significantly (P<0.05%) increased biomass production of sunflower in comparison to organic or chemical fertilizers alone. Agele and Taiwo (2013) reported that the highest values of root and shoot biomass of sunflower were obtained from plots amended with cow dung manure over the control. Adebayo *et al.* (2010) found that addition of cow dung produced significantly higher flower diameter (12.13cm) in sunflower and head weight (39.3g) at harvest. Naing *et al.* (2010) showed that the combination of FYM and inorganic fertilizers significantly increased the yield of dry matter of shoot of rice over the control.

Variations in value of seed yield parameters are significant (P< 0.05) due to treatments of cow dung and NPK. The highest yield of seed (64.7g plant^{-1}), number of seeds (735.7 plant^{-1}) and 100 seeds weight (9.8g) were found in the treatments, 7.5t CD ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1}, 5t CD ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1} and 7.5t CD ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1} respectively (Table 4.3). Among the sole cow dung treatments, the highest doses of cow dung (7.5t CD ha^{-1}) contributed higher growth except leaf area, leaf area index and yield of petiole. However, the performances of sole NPK fertilizers were found better than the sole cow dung treated treatments. Combined application of NPK fertilizers and cow dung produced better results significantly (P<0.05%) in most of the cases but some treatments showed statistically identical results among the treatments. The highest combination of NPK fertilizers and cow dung (7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}) showed the best result in most of the cases of growth and yield attributes but the desirable best yield of seeds was obtained at the highest dose of cow dung and medium dose of NPK fertilizers which belonged to the treatment, 7.5t CD ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}. On the basis of seed yield, the treatments may be arranged in the order of 15>14>13>16>12> 9>11>8>6>10>7>5>4>3>2>1. These findings indicate that combined use of NPK fertilizers and cow dung is better for obtaining higher yield.

Similar results were found by Esmaeilian *et al.* (2012) and Shoghi-Kalkhoran *et al.* (2013). Agele and Taiwo (2013) further reported that higher seed weight of sunflower per plant and per plot were obtained from plots amended with organic and inorganic fertilizers. Akbari *et al.* (2011) reported that maximum grain yield of sunflower was obtained with equal amounts of farm yard manure and N fertilizer application. Adebayo *et al.* (2010) results indicated that cow dung significantly produced higher flower diameter (12.13cm) and head weight (39.3g) of sunflower at harvest**.** Filho *et al.* (2013) found that highest dose of cattle manure (20% v/v) had a better performance on number of seeds $plant^{-1}$, weight of seeds $plant^{-1}$, weight of 1000 seeds and the outer diameter of the capitulum $head^{-1}$ of sunflower than other treatments. Scheiner *et al.* (2002) suggested that excessive N fertilization of sunflower not only generates that environmental risk, it may also affect to reduce seed yield through an increase of plant lodging. Lukman *et al*. (2016) reported that complementary application of cow dung @ 10t ha^{-1} and inorganic fertilizers (NPK @ 20-10-10kg ha^{-1}) significantly ($P<0.05$) improved the grain yield and number of panicles per plant considerably except thousand grain weight of rice. Haque *et al.* (2015) found that the maximum doses of cow dung and poultry litter (9t ha^{-1} and 11 t ha^{-1}) showed the best performance on pod yield (3.24 kg $plot^{-1}$ or 9t ha^{-1}) of okra. Shahariar *et al*. (2013) reported that among the treatments applied, the highest head yield of cabbage (97.6 t ha^{-1}) was obtained from RDF +5t ha^{-1} digested PL bio-slurry which was 366% higher than the control. Sanyal *et al.* (1993) revealed that groundnut cv. JI-24 yields were significantly higher with application of 75% RDF +10 t FYM ha^{-1} than application of 100 or 150 RDF in a potato-groundnut-rice cropping sequence. Omogoye and Adewale (2015) reported that the combined application of CD and NPK (20-10-10kg ha^{-1}) significantly enhanced yield of chilli pepper over the control. Naing *et al.* (2010) showed that the combination of cattle manure (@ 10 t ha^{-1}) NPK (@ 50-22-42 kg ha^{-1}) increased significantly grain number per panicle and thus yield of rice.

8.1.2 Effects of NPK and rice bran

The highest plant height (196.0cm), the number of leaf (45.5plant^{-1}), leaf area (384.4cm^2) and leaf area index (13.6) were found in the integrated treatments of 7.5t RB ha^{-1} + $N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, respectively, at maturity of sunflower (Tables 5.1- 5.2). The values were also statistically significant ($P<0.05$).

The findings of the present investigation are in consent with the findings of other workers. Bader and Qureshi (2014) reported that significantly improved growth of sunflower plants *viz.* shoot and root lengths as compared to control plants treated with undecomposted organic fertilizer. Rasool *et al.* (2013) found that application of organic manures @ 10 and 20 t ha^{-1} was at par with each other but recorded significantly ($P< 0.05$) improvement in the plant height, leaf area index and dry matter production of sunflower after 25 days of sowing. Kamara *et al.* (2015) observed that plant height, tiller number of both rice varieties grown in soils amended with rice straw biochar were significantly higher than that grown on untreated soil. Moghadam and Heidarzadeh (2014) also reported that combined application of rice husk and mineral fertilizer increased height, number of tiller, leaf area and leaf length of rice plant significantly ($P<0.01\%$). Abrishamkesh *et al.* (2015) found that effects of applying rice husk biochar significantly increased the growth of lentils. Sarah *et al.* (2013) recorded that the rice husk biochar treatments also increased plant height and number of leaves in all the crops (*lettuce- cabbage-lettuce)* in comparison to no biochar treated plants. Lee (2010) showed that the sesame oil cake, rice bran and molasses did not reduce onion height, leaf number or bulb diameter as compared to chemical fertilizer. Islam *et al.* (2019) reported that the application of waste concern organic fertilizer in combination with chemical fertilizer significantly increased height and panicle number of T. amon rice. Mohsin *et al.* (2019) reported that the highest plant height (17.2 cm) and number of leaves mungbean (14.3plant^{-1}) recorded in P @ 5 and K @ 10 kg ha^{-1} treatment at harvest.

The results showed that the highest dry weight of root (16.0g plant^{-1}) was found in the treatments, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t RB ha^{-1} + $N_{120}P_{90}K_{150}$kg ha^{-1} applied jointly (Table 5.3). The highest dry weight of stem (67.3g plant^{-1}) and dry matter yield (127.7g plant^{-1}) or (6.6t ha^{-1}) were found in the treatment, 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 5.3). The highest dry weight of leaf (24.0g plant^{-1}) dry weight of petiole (5.8g plant^{-1}), respectively, were found with the treatment, 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1} at maturity of sunflower plant (Table 5.3). The highest dry weight (18.0g plant^{-1}) and maximum diameter of inflorescence (52.7cm plant^{-1}) were found in the treatment, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 5.3). The values of all growth and dry matter yield parameters were found significantly (P< 0.05) better in most of the cases than the control.

These findings are in good consent with the observations of other investigators. Kamara *et al.* (2015) found that dry biomass weight of two rice varieties grown in soils amended with rice straw biochar were significantly higher than those grown on untreated soil. Similarly, Pratiwi and Shinogi (2016) reported that the dry weight of shoot of rice plants was significantly higher in soil amended with 4% biochar than that in the control soil. Sarah *et al.* (2013) also observed that the rice husk biochar treatments were found to increase the shoot and root biomass in all the cropping of a three crop (*lettuce- cabbage-lettuce)* cycle in comparison to no biochar treatments. Application of FYM @ 10 t ha^{-1} + rice hull ash @ 2t ha^{-1} +100% RDF recorded highest straw yield (7.49 t ha^{-1}) of rice (Yankaraddi *et al.*, 2009). Moghadam and Heidarzadeh (2014) showed that combined application of rice husk and mineral fertilizer increased total dry weight of rice plant significantly at 1% level in tillering stage. Use of manures and fertilizers alone and in combination on soybean and concluded that highest amounts of straw yield recorded by conjoint use of manures and fertilizers (Patil *et al.*, 2008). Application of waste concern organic fertilizer in combination with chemical fertilizer significantly increased panicle number and straw yields of T. amon rice over control in two AEZs (Islam *et al.*, 2019). Mohsin *et al.* (2019) observed that the highest amount of dry matter yield (1.88 g plant^{-1}) was recorded in P @ 5kg ha^{-1} +K @ 12kg ha^{-1} treatment. The overall best dose was P @ 5kg ha^{-1} +K @ 12kg ha^{-1}.

Average seeds yield parameters i.e. the highest dry weight of seeds (46.0g plant^{-1}) and the highest number of seeds (638.9 plant^{-1}) were found significantly (P< 0.05) higher in the treatment, 7.5t RB ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1}. Significantly (P< 0.05) the higher 100 seed weight (7.3g) was found in the treatment, 5t RB ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1}. Among the sole rice bran treatments, the highest dose of rice bran (7.5t RB ha^{-1}) contributed maximum in growth and yield of the crop (Table 5.3). Application of NPK fertilizers also followed the same trend except diameter of inflorescence but sole NPK fertilizers showed better results than the sole rice bran treated treatments. Combined application of NPK fertilizers and rice bran produced better results significantly (P<0.05%) in most of the cases but some treatments showed statistically identical results among the treatments. The highest and medium combination of NPK fertilizers and rice bran showed better results in most of the cases. The desirable yield of seeds was obtained at the highest dose of rice bran and medium dose of NPK fertilizers which belong to the treatment, 7.5t RB ha^{-1} +$N_{80}P_{60}K_{100}$kg ha^{-1}. On the basis of seed yield, the treatments may be arranged in the order of 15>10>13>9>14>8>11>6>7>12>16>5>4> 3>2>1. These findings indicate that combined use of NPK fertilizers and rice bran is better for obtaining higher yield.

These observations are in agreement with the findings of the workers of else where. These results are in similarity with Patil *et al.* (2008), although the dissimilar test crop, who studied the effects of use of manures and fertilizers alone and in combination on soybean and concluded that highest amounts of grain yield recorded by conjoint use of manures and fertilizers. Moghadam and Heidarzadeh (2014) observed that combined application of rice husk and mineral fertilizer increased rice grain yield significantly at 5% level. Application of FYM @ 10 t ha^{-1} + rice hull ash @ 2 t ha^{-1} +100% RDF recorded the highest grain yield (6.24 t ha^{-1}) of rice (Yankaraddi *et al.*, 2009). Reports are available that in rice husk treatment, tuber yield, tuber number per plant and mean tuber weight of potato were as high as in farmyard manure and farmyard manure + rice husks (Semiha, 2009). The author also showed that total and quality yield of potato increased markedly with the application of rice husk. Mahrous *et al.* (2014) reported that various rates of compost, natural mineral rocks and biofertilizers increased head diameter, seed yield $plant^{-1}$, seed yield $faddan^{-1}$ and 100 seeds weight were 4 %, 5 %, 13 % and 5 % as compared to recommended NPK mineral fertilizer, respectively, at the first season. The corresponding values at the second one were 4 %, 8 % 19 % and 3 % in the same order. Application of rice husk dust significantly increased maize grain yield than control (Uguru *et al.,* 2015). Moyin- Jesu (2015) reported negatives opinion that the highest values of cabbage head yield parameters obtained with poultry manure followed by wood ash and rice bran, respectively. Similarly, the onion marketable yield was 45.9 ton ha^{-1} in the organic fertilizer and liquid organic fertilizer over mulch (OF/LOFoM) treatment, which exceeded that in the chemical fertilizer treatment by up to 1.9 ton (Lee, 2010). Islam *et al.* (2019) showed that the application of waste cotton organic fertilizer @ 1 t ha^{-1}+75% of NPKS (80-35-40-10) kg ha^{-1} produced higher crop yields. Similarly, Tejeswara Rao *et al.* (2013) reported that all the growth and yield attributes, yield (seed as well as stalk) harvest index of sunflower were at their best with recommended dose of fertilizer either with or without *Panchagavya* spray.

8.1.3 Effects of NPK and poultry litter

The results showed that significantly ($P< 0.05$) the highest plant height (204.3cm), number of leaf (44.8 plant^{-1}), maximum leaf area (376.4cm^2) and leaf area index (13.61) were found in the integrated treatment, (4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}) at maturity of sunflower (Tables 6.1-6.2).

These observations are in agreement with the findings of the other investigators working in this line. Buriro *et al.* (2015) reported that poultry manure and goat/sheep manure @ 6t ha^{-1} or @ 8 t ha^{-1} replacing 50% recommended dose of NPK fertilizers, respectively showed more promising growth results as compared to buffalo manure on plant height, stem girth and leaves plant^{-1} of sunflower plant. Addition of cassava peel and poultry manure (Cp3Pm), 5 t ha^{-1} (15.8g/pot) significantly ($P< 0.05$) recorded higher sunflower plant height (Adebayo *et al*., 2010). Kulkarni *et al.* (2002) found that application of poultry manure significantly increased the number of leaves plant^{-1}. Agbede *et al.* (2017) assessed that the highest plant height, number of leaves, root diameter, root length, and fresh root yield of carrot were obtain in the poultry manure and NPK fertilizers treatments. The overall best growth performance of *Gynura procumbens* was achieved in poultry litter compost treatment (Akon *et al.*, 2018). Moyin-Juse (2019) reported that cabbage head weight, head girth, head length, plant height, stem girth, leaf number and leaf area increased by 17, 18, 8, 17, 19, 10 and 16%, respectively, with application of poultry manure compost to NPK fertilizer. Similarly, and was significantly ($P< 0.05$) the highest height, leaf number and leaf area in arum were achieved in the combined application of decomposed poultry litter compost and nitrogen (Uddin *et al.*, 2018). Gani (2014) found that the highest plant height and base diameter were obtained with the integrated treatment of RDF N 50% from PL + 50% RDF. Haque *et al.* (2015) also showed that the highest level of poultry litter (11 t ha^{-1}) produced significantly ($P< 0.05$%) the best result on plant height, number of leaves, leaf length and leaf breadth of okra. Similarly, Abbas *et al*. (2013) reported that individually all the treatments (cotton waste compost alone and in combination with fertinemakil fertilizer) showed maximum sunflower plant growth character in terms of sunflower plant height, number of flowers, diameter of flowers.

The results showed that the highest dry weight of root (12.66g plant^{-1}), leaf (21.47g plant^{-1}), petiole (8.7g plant^{-1}) and total dry matter yield (134.0g plant^{-1}) or (7.0t ha^{-1}) were found in the treatment, 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} (Table 6.3). The highest dry weight of inflorescence (32.6g $plant^{-1}$) and maximum diameter of inflorescence (54.0cm $plant^{-1}$) were found in the treatment, 3t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1} (Table 6.3). The highest dry weight of stem (63.82g $plant^{-1}$) was found in the treatment, 1.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1} at maturity of sunflower plant (Table 6.3). The values of all growth and yield parameters were found significantly ($P< 0.05$) better over the control.

These observations are in agreement with the findings of other investigators working in this field. Kulkarni *et al.* (2002) reported that application of poultry manure significantly increased dry matter production $plant^{-1}$ of sunflower. Gani, (2014) reported that the highest dry matter production was found with (RDF 75% from PL + 25% RDF). Uddin *et al.* (2018) reported that dry weights of leaf, stem, bulb and root in arum were recorded the highest in the combined application of decomposed poultry litter compost and nitrogen. Abbas *et al*. (2013) also reported that individually all the treatments (cotton waste compost alone and in combination with fertinemakil fertilizer) showed maximum diameter of sunflower flowers.

Average of seed yield parameters i.e. the highest yield of seeds (44.4g $plant^{-1}$) and number of seeds (663.0 $plant^{-1}$) were found in the treatment, 4.5t PL ha^{-1}+$N_{40}P_{30}$ K_{50} kg ha^{-1}, and were significantly ($P< 0.05$) higher then the control (Table 6.3). Significantly ($P< 0.05$) the highest 100 seeds weight (7.40g) was found in the treatment, 3t PL ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1}. Among the sole poultry litter doses, the lowest dose (1.5t PL ha^{-1}) contributed maximum growth and yield except dry weight of inflorescence, diameter of inflorescence and dry weight of seed. Among the sole NPK fertilizers treatments, the highest dose NPK fertilizers contributed maximum growth and yield except dry weight of inflorescence, diameter of inflorescence. Sole NPK fertilizers produced better results than the sole poultry litter treated treatments. Combined application of NPK fertilizers and poultry litter produced significantly ($P<0.05\%$) better results in most of the cases but some treatments showed statistically identical results among the treatments. The highest combination of NPK fertilizers and poultry litter treated treatment (4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}) showed the best results in most of the cases. The desirable yield of seeds was highest at the highest dose of poultry litter and minimum dose of NPK fertilizers which belong to the treatment (4.5t PL ha^{-1}+ $N_{40}P_{30}K_{50}$kg ha^{-1}) (Table 6.3). On the basis of seed yield, the treatments may be arranged in the order of 14>13>11>12> 15>16>7>9>10>8>6>5>4>3>2>1. These findings indicate that combined use of NPK fertilizers and poultry litter is better for obtaining higher yield.

These observations are in good agreement with the findings of other investigators. Buriro *et al.* (2015) reported that poultry manure and goat/sheep manure @ 6t ha^{-1} or @ 8 t ha^{-1} replacing 50% recommended dose of NPK fertilizers, respectively, showed more promising results as compared to buffalo manure *viz.* head diameter, seeds $head^{-1}$, seed weight $head^{-1}$ and seed yield of sunflower plant. Prasanthrajan *et al.* (2014) reported that the coir pith and rock phosphate added poultry compost along with recommended dose of NPK recorded higher sunflower yield and saved 25% of inorganic fertilizer. Kulkarni *et al.* (2002) observed that application of poultry manure significantly increased the number of filled grains $head^{-1}$ and grain weight $plant^{-1}$ of sunflower. Munir (2007) showed that the maximum sunflower seed yields of 2895 kg ha^{-1} and 2792 kg ha^{-1} were obtained with the treatment of 50-75-50 NPK kg ha^{-1} + poultry manure @ 8 t ha^{-1} and poultry manure produced higher yield than FYM. Organic manure in combination with the recommended dose of chemical fertilizers can be applied to achieve significantly better yield and yield attributing parameters of BINA soybean-2 (Karim *et al.*, 2013). Effectiveness of integrated poultry manure and chemical fertilizer on maize yield components were reported to be higher than the only single fertilizer application (Fallah *et al.*, 2007). Ayoola and Adeniyan (2006) showed that crop yields increased significantly with the NPK + poultry manure than either NPK alone or control. The percentage of crude fiber, total nitrogen and carbohydrate contents of cowpea were found to be clearly highest with poultry manure and inorganic fertilizer treatment (Amujoyegbe and Alofe, 2003). However, in the monocrop experiments, aubergine, cabbage, and tomoto gave higher yield when treated with poultry manure and NPK (Latthif and Maraikar, 2003). The highest yield of fibre and stalk were obtained with the integrated treatment of N 50% from PL + 50% RDF (Gani, 2014). Ayoola and Adeniyan (2006) observed that crop yields increased significantly ($P< 0.05$) with NPK+ poultry manure than either NPK alone. Similarly, Abbas *et al*. (2013) observed that individually all the treatments (cotton waste compost alone and in combination with fertinemakil fertilizer) showed maximum plant growth character in terms of number of sunflower flowers, diameter of flowers and 1000 grains weight.

8.1.4 Effects of NPK and vermicompost

Results showed that the tallest plant (198.4cm), the highest number of leaf (45.3 plant^{-1}), the maximum leaf area (381.0cm^2) and the highest leaf area index (14.62) were found in the combined treatments of 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, 7.5t VC ha^{-1}+N_{120} $P_{90}K_{150}$kg ha^{-1}, 7.5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t VC ha^{-1} +N_{120} $P_{90}K_{150}$kg ha^{-1}, respectively, at maturity of sunflower plant which were statistically significant (P< 0.05) (Tables 7.1-7.2).

The present observations are in agreement favorably well, with the findings of other workers. Godavari *et al.* (2017) reported that application of 100% RDF with vermicompost @ 2.5 t ha^{-1} recorded the highest plant height, head diameter of sunflower. Similarly, Oshundiya *et al.* (2014) reported that application of organic fertilizer significantly (P<0.05) increased plant height of early and late sown sunflower. Mondal *et al.* (2017) reported that the performance of the crop was adjudged in terms of various parameters *viz.* leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR) etc of mustard. All the growth parameters of wheat in vermicompost treatments varied significantly from control although differences within various treatments were found not significant (Joshi *et al.*, 2013). Subler *et al.* (1998) reported that increase in leaf areas occurred due to application of 10% vermicompost and 90% Metro Mix 360 combinations as compared with 100% MM360. The maximum range of root length, shoot length, leaf length and number of leaves plant^{-1} in garlic was observed in the treatment, 15 t ha^{-1} VC + 50 % NPK (Suther, 2009). Zaman *et al.* (2018) reported that vermicompost along with different rates of chemical fertilizers exerted significant influence on the growth parameters of stevia receiving VC 7.5 t ha^{-1} + 75% chemical fertilizers.

The results further showed that significantly (P< 0.05) the highest dry weight of root (18.87g plant^{-1}), stem (72.4g plant^{-1}), inflorescence (38.3g plant^{-1}) and total dry matter yield (153.9g plant^{-1}) or (7.99t ha^{-1}), respectively, were found in the treatment, N_{120} $P_{90}K_{150}$kg ha^{-1} (Table 7.3). The highest dry weight of leaf (19.2g plant^{-1}) was found in the treatment, 2.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. The highest dry weights of petiole (7.7g plant^{-1}) and diameter of inflorescence (62.3cm plant^{-1}), respectively, were recorded in the treatment, 5t VC ha^{-1}+ N_{120} $P_{90}K_{150}$kg ha^{-1} (Table 7.3). The values of all growth and dry matter yield parameters were found to increase significantly (P< 0.05) over the control.

These observations are in agreement with the findings of Subler *et al.* (1998) who reported that significant increase in tomato seedling weights after substitution of 10% and

20% vermicompost into MM360. Moreover, significant increase in the total plant weights were also obtained due to application of 10% vermicompost and 90% Metro Mix 360 combinations when compared with 100% MM360. Vadiraj *et al*. (1998) revealed that the herbage yield was maximum (6067.5kg ha^{-1}) in Rcr-41 when 15 t ha^{-1} of vermicompost was applied. Zaman *et al.* (2018) reported that leaf biomass yield and stevioside content of stevia were found higher in the treatment of VC 7.5 t ha^{-1} + 75% chemical fertilizer.

Value of seed yield parameters increased significantly ($P< 0.05$). The highest dry weight of seeds (57.61g $plant^{-1}$), number of seeds (676.7 $plant^{-1}$) and 100 seed weight (7.53g) were found in the treatments, 5t VC ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1}, 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively (Table 7.3).

Among the sole vermicompost treatments, the highest dose of vermicompost, (7.5t VC ha^{-1}) contributed maximum growth and yield in all the cases. Similarly, the sole NPK fertilizers followed the same trend except in case of leaf area of growth parameter. However, the sole NPK fertilizers were found to produce better results than the sole vermicompost treated treatments. Further more, it was noticed that highest dose of NPK fertilizers ($N_{120}P_{90}K_{150}$kg ha^{-1}) showed better results in most of the cases. The desirable yield of seeds was obtained in medium dose of NPK fertilizers and vermicompost which belonged to the treatment, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. On the basis of seeds yield production, the treatments may be arranged in the order of 12>13>15>14>10>11>16> 9>7>8>6>5>4>3>2>1 The findings indicated that combined use of NPK fertilizers and vermicompost is better for obtaining higher grain yield.

These observations are in good agreement with the findings of other investigators working in this area of interest. Application of 50% recommended dose of nitrogen fertilizer as urea along with 50% N as vermicompost recorded the highest seed yield of 1140 kg ha^{-1} followed by FYM and bone sludge substitution with yields of 995 and 930 kg ha^{-1} respectively in sunflower (Baradhan *et al.*, 2006). The growth of tomatoes, lettuces and peppers were reported to the best at substitution into soils at rates of 8-10%, 8% and 6% respectively, using duck waste vermicompost and peat mixture (Buckerfield *et al.*, 1999). Sharma *et al.* (2014) reported that among all the treatments, vermicompost (VC) +Fert at 25+25 kg N ha^{-1} recorded the highest grain yields of sunflower during both rabi and kharif seasons. Godavari *et al.* (2017) showed that application of 100% RDF with vermicompost @ 2.5 t ha^{-1} recorded the highest 100 seed weight and seed yield of sunflower. Vadiraj *et al*.

(1998) also revealed that seed yield was recorded maximum in Rcr-41 (1314kg ha^{-1}) in plants treated with 20t ha^{-1} vermicompost. Similarly for crops other then sunflowering, the yield parameters of wheat in vermicompost treatments varied significantly from control although differences within various vermicompost treatments were found not significant (Joshi *et al.*, 2013). Suther (2009) further reported that the maximum fruit weight, number of cloves in garlic fruit were recorded in the treatment, 15 t ha^{-1} VC + 50% NPK. The author also revealed that the average fruit weight was approximately 26.4% greater in 15 t ha^{-1} VC + 50% NPK than recommended NPK treatment. Mondal *et al.* (2017) observed that 25% reduced dose of chemical fertilizer and its combination with vermicompost was optimum for mustard production.

8.2 Effects of NPK and organic manures on concentration and uptake of NPKS of different organs of sunflower plant

Results showed that sole application of NPK fertilizers, sole organic manures i.e. cow dung, rice bran, poultry litter and vermicompost and their different combinations caused significant ($P< 0.05\%$) changes in nutrient concentration and uptake in most of the cases. All the treatments showed higher nutrient concentrations and uptake over the control.

8.2.1 Effects of NPK and cow dung

The values of NPKS concentration varied from 0.29 to 1.33, 0.16 to 0.33, 0.55 to 1.85, and 0.04 to 0.19% in stem; 0.35 to 1.08, 0.17 to 0.38, 0.66 to 2.04, and 0.02 to 0.18% in root; 2.37 to 3.45, 0.22 to 0.67, 1.80 to 4.12, and 0.07 to 0.18% in leaf; 0.37 to 1.99, 0.16 to 0.62, 0.65 to 3.0, and 0.05 to 0.22% in petiole; 0.28 to 0.73, 0.15 to 0.68, 0.71 to 2.25, and 0.03 to 0.23% in inflorescence; and 4.0 to 4.95, 0.27 to 0.94, 0.16 to 0.75, and 0.04 to 0.26% in seed respectively (Tables 4.4-4.9). The highest concentrations of N, P and S (4.95, 0.94, 0.26%) in seed, respectively, were found in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1} and 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and K (4.12%) in leaf was found in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. The lowest concentrations of N (0.28%) and P (0.15%) in inflorescence, K (0.16%) in seed and S (0.02%) in root, respectively, were found in control treatment applied to sunflower plant (Tables 4.4-4.9).

The values of uptake of NPKS ranged from 29.0 to 532.0, 16.0 to 188.1, 55.0 to 995.0, and 4.0 to 79.8 mg plant^{-1} in stem; 2.9-111.7, 1.41 to 39.3, 5.48 to 210.7, and 0.18 to 14.88 mg plant^{-1} in root; 158.1 to 739.6, 14.7 to 129.5, 120.1 to 889.1, and 4.7 to 35.5 mg plant^{-1} in leaf; 5.6 to 188.0, 2.4 to 62.0, 10.0 to 300.0, and 0.8 to 22.0 mg plant^{-1} in petiole; 16.8 to 141.1, 9.0 to 150.8, 42.6 to 434.9, and 1.8 to 44.5 mg plant^{-1} in inflorescence; and 312.0 to 3115.0, 21.1 to 601.7, 12.5 to 429.8, and 3.12 to 100.9 mg plant^{-1} in seed respectively (Tables 4.4-4.9). The highest uptakes of N (3115.0 mg plant^{-1}), P (601.7 mg plant^{-1}) and S (100.9 mg plant^{-1}) in seed, respectively, were found in the treatments, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and K (995.0 mg plant^{-1}) in stem was found in the treatment, 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} of sunflower plant. The lowest uptakes of N (2.9 mg plant^{-1}), P (1.41 mg plant^{-1}), K (5.48 mg plant^{-1}) and S (0.18 mg plant^{-1}) in root, respectively, were found in control treatment applied to sunflower plant (Tables 4.4-4.9).

Similar results were also found by Esmaeilian *et al.* (2012) who observed that combination of cattle manure and NPK fertilizer produced the highest N, P and K content in different organs of sunflower. Similarly, Naveen (2009) revealed that significantly higher N, P and K uptake was noticed in combined treatments of cow dung along with NPK fertilizer over the control. Rao *et al.* (2013) also observed that nitrogen uptakes of sunflower were at their best with recommended dose of fertilizer either with or without *Panchagavya* spray.

8.2.2 Effects of NPK and rice bran

The values of NPKS concentration ranged from 1.07 to 1.22, 0.11 to 0.35, 0.62 to 1.90, and 0.07 to 0.18% in stem; 0.52-1.17, 0.09 to 0.35, 0.89 to 2.41, and 0.07 to 0.16% in root; 2.18 to 3.98, 0.28 to 0.43, 2.56 to 4.28, and 0.10 to 0.24% in leaf; 0.53 to 1.04, 0.14 to 0.65, 0.56 to 3.00, and 0.04 to 0.22% in petiole; 0.36 to 2.16, 0.09 to 0.58, 0.75 to 2.21, and 0.05 to 0.26% in inflorescence; and 3.17 to 5.24, 0.43 to 0.83, 0.57 to 1.60, and 0.13 to 0.47% in seed respectively (Tables 5.4-5.9). The highest concentrations of N, P and S (5.24, 0.83, 0.47%), respectively, in seed were found in the treatments, 5t RB ha^{-1}+$N_{120}\,P_{90}\,K_{150}$ kg ha^{-1}, 7.5t RB ha^{-1} and 5t RB ha^{-1} respectively. Maximum K (4.28%) in leaf was observed in treatment, $N_{120}P_{90}K_{150}$kg ha^{-1} applied to sunflower plant. The lowest concentrations of N (0.36%) in inflorescence, P (0.09%) in root and inflorescence, K (0.56%) and S (0.04%) in petiole, respectively, were found in control treatment given to sunflower plant (Tables 5.4- 5.9).

The values of uptake of NPKS varied from 85.6 to 787.4, 8.8 to 200.6, 49.6 to 998.6, and 5.6 to 111.7 mg plant^{-1} in stem; 5.2 to 187.2, 0.9 to 56.0, 8.9 to 344.0, and 0.7 to 19.2 mg plant^{-1} in root; 152.6 to 903.5, 19.6 to 97.6, 179.2 to 971.6, and 7.0 to 55.2 mg plant^{-1} in leaf; 6.9 to 59.3, 1.8 to 37.1, 7.3 to 171.0, and 0.5 to 12.8 mg plant^{-1} in petiole; 14.4 to 365.4, 3.6 to 93.6, 30.0 to 338.1, and 2.0 to 41.4 mg plant^{-1} in inflorescence; and 231.4 to 2396.6, 31.4 to 345.0, 41.6 to 547.2, and 9.5 to 115.0 mg plant^{-1} in seed respectively (Tables 5.4- 5.9). The highest uptakes of N (2396.6 mg plant^{-1}), P (345.0 mg plant^{-1}) and S (115.0 mg plant^{-1}) in seed, respectively, and K (998.6 mg plant^{-1}) in stem were found in the same treatment, 7.5t RB ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1} given to sunflower plant. The lowest uptakes of N (5.2 mg plant^{-1}), P (0.9 mg plant^{-1}) and K (0.7 mg plant^{-1}) in root, and S (0.5 mg plant^{-1}) in petiole, respectively, were found in control treatment applied to sunflower plant (Tables 5.4- 5.9).

These findings are in consistent with the observations of Bader and Qureshi (2014) who reported that composted rice husk improved mineral nitrogen and phosphorus contents of sunflower plants. Yankaraddi *et al.* (2009) also showed that application of FYM @ 10 t ha^{-1} + rice hull ash @ 2 t ha^{-1} +100% RDF recorded the highest nutrient content (2.51% N, 0.61% P and 2.91 % K) and nutrient uptake (170.66 N, 41.14 P and 209.76 K kg ha^{-1}) in rice plant. In this context, Akter *et al*. (2017), further, reported that the primary nutrition (NPK) of rice had better response in saline soil, which received rice hull, rice straw and saw dust. Mohsin *et al.* (2019) also reported that the maximum concentration of nitrogen in root, stem and leaf of mungbean were 1.59, 2.51 and 3.82% in the treatments, P @ 5kg and K @ 12kg ha^{-1}, P @ 10kg and K @ 12kg ha^{-1}, and P @ 10kg and K @ 18kg ha^{-1}.

8.2.3 Effects of NPK and poultry litter

The values of NPKS concentration varied from 0.20 to 0.65, 0.13 to 0.42, 0.64 to 1.80, and 0.04 to 0.17% in stem; 0.39-1.02, 0.11 to 0.54, 0.36 to 1.54, and 0.07 to 0.18% in root; 1.37 to 4.47, 0.40 to 0.57, 1.44 to 3.14, and 0.07 to 0.20% in leaf; 0.38 to 2.60, 0.05 to 0.64, 0.61 to 3.20, and 0.03 to 0.32% in petiole; 0.28 to 1.30, 0.06 to 0.95, 0.62 to 2.19, and 0.07 to 0.32% in inflorescence; and 2.89 to 5.18, 0.26 to 0.86, 0.44 to 1.02, and 0.15 to 0.31% in seed respectively (Tables 6.4- 6.9). The highest concentrations of N (5.18%) in seed, P (0.95%) in inflorescence, K (3.20%) in petiole and S (0.32%) in petiole and inflorescence were found in treatments, 3t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}, 4.5t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}; and 1.5t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1} and 4.5t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}), respectively, applied to sunflower plant. The lowest concentration of N (0.20%) in stem, P (0.05%) and S (0.03%) in petiole and K (0.36%) in root, respectively, were found in sunflower plant grown in control conditioned (Tables 6.4- 6.9).

The values of uptake of NPKS ranged from 33.1 to 381.6, 21.5 to 256.6, 106.0 to 997.9, and 6.6 to 99.8 mg plant^{-1} in stem; 9.5 to 111.6, 2.7 to 64.6, 8.8 to 195.0, and 1.7 to 19.4 mg plant^{-1} in root; 86.2 to 747.4, 18.9 to 95.3, 90.6 to 659.1, and 4.4 to 40.8 mg plant^{-1} in leaf; 7.2 to 226.2, 1.0 to 50.5, 11.6 to 278.4, and 0.6 to 17.4 mg plant^{-1} in petiole; 15.1 to 384.8, 3.2 to 281.2, 33.5 to 648.2, and 3.8 to 94.7 mg plant^{-1} in inflorescence; and 213.9 to 2294.7, 19.2 to 381.0, 32.6 to 447.4, and 11.1 to 128.5 mg plant^{-1} in seed respectively (Tables 6.4- 6.9). The highest uptakes of N (2294.7 mg plant^{-1}), P (381.0mg plant^{-1}) and S (128.5mg plant^{-1}) in seed, and K (997.9 mg plant^{-1}) in stem, respectively, were found in the treatment (3t PL ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}) applied to sunflower plant. The lowest uptakes of N (7.2 mg plant^{-1}), P (1.0 mg plant^{-1}) and S (0.6 mg plant^{-1}) in petiole and K (8.8 mg plant^{-1}) in root, respectively, were found, in control treatment given to sunflower plant (Tables 6.4- 6.9).

These findings are in consent with the results of Sharma *et al.* (2014) recorded that conjunctive nutrient treatments proved quite superior to other set of treatments in improving the uptake of N, P, K and S and micronutrients in sunflower plant and their build up in the soil. Gani (2014), conducted experiment in Manikgonj also reported that the highest content and uptake of N, P, K and S were found with integrated treatment of RDF N 100% from PL + 100% RDF in jute plant. The author, further, reported that the highest content of N (2.56%), P (0.56%), K (2.57%) and S (0.073%) in jute plant were found in integrated treatment of RDF N 100% from PL + 100% RDF from experiment conducted at Keishoreganj. Tejeswara Rao *et al.* (2013) also reported that the highest phosphorus uptake of sunflower was recorded with poultry manure either with or without the spray of *Panchagavya*. Similarly, Esmaeilian *et al.* (2012) also revealed that combination of poultry manure and chemical fertilizer led to the highest P content and sheep manure application resulted to the highest K content.

8.2.4 Effects of NPK and vermicompost

The value of NPKS concentrations ranged from 0.22 to 0.42, 0.05 to 0.23, 0.72 to 1.95, and 0.03 to 0.12% in stem; 0.32-0.57, 0.13 to 0.33, 0.54 to 2.66, and 0.07 to 0.20% in root; 1.87 to 2.61, 0.12 to 0.42, 0.84 to 2.77, and 0.06 to 0.19% in leaf; 0.39 to 2.30, 0.09 to 0.65, 0.83 to 2.65, and 0.06 to 0.20% in petiole; 0.22 to 0.76, 0.10 to 0.71, 0.59 to 2.21, and

0.06 to 0.26% in inflorescence; and 2.80 to 4.86, 0.33 to 0.69, 0.56 to 1.08, and 0.10 to 0.16% in seed respectively (Tables 7.4- 7.9). The highest concentration of N (4.86%) in seed, P (0.71%) and S (0.26%) in inflorescence and K (2.77%) in leaf were found in the treatments, 2.5t VC ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1} and 7.5t VC ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}, respectively, applied to sunflower plant. The lowest concentration of N (0.22%) in stem and inflorescence, P (0.05%) and S (0.03%) in stem and K (0.54%) in root, respectively, were found in controlled sunflower plant (Tables 7.4- 7.9).

The value of uptakes of NPKS ranged from 15.2 to 304.1, 3.50 to 115.8, 49.7 to 999.6, and 2.1 to 76.8 mg plant^{-1} in stem; 6.8 to 84.9, 2.8 to 41.6, 11.6 to 341.8, and 1.5 to 23.8 mg plant^{-1} in root; 93.5 to 476.2, 6.0 to 65.1, 42.0 to 446.0, and 3.0 to 30.6 mg plant^{-1} in leaf; 6.6 to 165.6, 1.5 to 46.8, 14.1 to 190.8, and 1.0 to 15.4 mg plant^{-1} in petiole; 9.8 to 278.2, 4.9 to 218.0, 28.9 to 678.5, and 2.9 to 80.5 mg plant^{-1} in inflorescence; and 226.0 to 2655.8, 26.6 to 382.5, 42.2 to 571.0, and 8.10 to 92.2 mg plant^{-1} in seed, respectively, of sunflower plant (Tables 7.4- 7.9). The highest uptake of N (2655.8 mg plant^{-1}), P (382.5 mg plant^{-1}) and S (92.2 mg plant^{-1}) in seed, and K (999.6 mg plant^{-1}) in stem were found in the treatments, 5t VC ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1}, 5t VC ha^{-1}+N_{120} P_{90} K_{150} kg ha^{-1}, 5t VC ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1} and 7.5t VC ha^{-1}+N_{80} P_{60} K_{100} kg ha^{-1}, respectively, applied to sunflower plant. The lowest uptakes of N (6.6 mg plant^{-1}), P (1.5 mg plant^{-1}) and S (1.0 mg plant^{-1}) in petiole and K (11.6 mg plant^{-1}) in root, respectively, were found in controlled sunflower plant (Tables 7.4- 7.9).

These findings are in consent with the observations of Kademani *et al.* (2003) who observed that the highest uptakes of NPK of different organs of sunflower crops were recorded in vermicompost treatment followed by FYM, cotton stock and maize residue. Similarly, Zaman *et al.* (2018) also reported that the highest N, P, K and S uptake of stevia were found in the treatment, 7.5 t VC ha^{-1} + 75% chemical fertilizer. Suther (2009) reported that vermicomposted manure may be a potential source of plant nutrients for sustainable crop production. The highest potassium uptake by sunflower plant was found with vermicompost either with or without the spray of *Panchagavya* (Tejeswara Rao *et al.*, 2013). Sharma *et al.* (2014) also reported that conjunctive nutrient treatment, vermicompost +chemical fertilizers proved quite superior to other set of treatments in improving the uptake of N, P, K, S and micronutrients in sunflower.

8.3 Quality of sunflower seed

Seed quality is an important parameter for producing edible oil and other purposes of sunflower seeds. Oil and protein contents are the initial required parameters for seed quality assessment.

8.3.1 Influence of NPK and cow dung

Quality of seed was assessed in terms of oil and protein contents analyzed.

Results showed that oil content increased with the increase of NPK fertilizers and CD applied at different combinations over the control in most of the cases. Highest and medium doses of NPK and CD showed better result to the yield of oil content. The oil content ranged between 35.6 and 51.8% (Table 4.10). The highest oil content (51.8) was observed in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}. Similarly, the lowest oil content was recorded in the treatment, 5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} which lower than the control (Table 4.10). On the basis of oil content, the efficiency of treatments may be arranged in the order of 13>15>8>7>5> 6>11>16>3>9>4>1>10>14>2>12.

Present finding are in good agreement with the finding of Naveen (2009). Akbari *et al.* (2011) reported that the highest oil content in sunflower seed was recorded in the treatments 100% FYM and 50% FYD + 50% N, respectively. Esmaeilian *et al.* (2012) reported that combination of cattle manure and NPK fertilizer produced higher oil content in sunflower seed in comparison to control. Shoghi-Kalkhoran *et al*. (2013) cited that the integrated application of fertilizers significantly ($P<0.05\%$) increased oil yield of sunflower seed in comparison to organic or chemical fertilizers applied alone. Scheiner *et al.* (2002) suggested that excessive N fertilization of sunflower not only generates the environmental risk, it may also affect the grain quality, decreasing its oil content reducing yield through an increase of plant lodging.

Protein content is an important parameter next to oil content of sunflower seed. It ranged from 23.4 to 30.2% (Table 4.10). The highest protein content (30.2%) was found in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} could be attributed to higher nitrogen content in seed (4.95%) compared to 3.72% in the treatment, 2.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}. The lowest protein content was found (23.4%) in the treatments, $N_{40}P_{30}K_{50}$kg ha^{-1} and 2.5t CD ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1} those accounted lower nitrogen content in seed (3.75 and 3.72%) and even than the control (Table 4.10). The results further showed that protein content was increased with the increasing rate of NPK fertilizers and cow dung in some cases. On the basis of protein content, the treatments could be arranged in the order of 13>15>4>10>11>14>2>3> 16> 9>12>1>7>6>5>8.

Similar results were found by Esmaeilian *et al.* (2012) who showed that combination of cattle manure and NPK fertilizer produced higher protein content of sunflower seed. Akbari *et al.* (2011) also reported similar results from sunflower seed due to combined treatment of FYM and N over FYM alone. Similarly, Shoghi-Kalkhoran *et al.* (2013) cited that the integrated effects of organic manure and fertilizers increased significantly (P< 0.05%) protein content of sunflower in comparison to organic or chemical fertilizers applied alone.

8.3.2 Influence of NPK and rice bran

Quality of seed was judged in terms of oil and protein contents revealed that oil content increased with the increase of NPK fertilizers and rice bran over the control treatment. The variations among the treatments were found to be significant in most of the cases. The oil content ranged from 39.0 to 51.1%. The highest oil content (51.1%) was observed in the treatment, 5t RB ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}. Over the lowest content produced in the treatment, 2.5t RB ha^{-1} which was even lower than the control (Table 5.10). The efficiency of treatments may be arranged in the order of 13>15>11>10>16>5>9>6>12>3>8> 14>4>7>2>1, so far oil content is concerned.

These results are in agreement with the finding of Tejeswara Rao *et al.* (2013) who reported that the highest oil content of the seed of sunflower was recorded with neem leaf manure in combination with *Panchagavya*. The author, further, revealed the significantly higher oil content than with the fertilizer either with or without the use of *Panchagavya* on sunflower. Similarly, Rasool *et al.* (2013) reported that application of organic manure @ 10 and 20 t ha^{-1} increased the oil yield of sunflower by 11 and 5.4%, respectively, over no application of FYM. The author, further, revealed that with increased N dose, the oil content consistently decreased but the oil yield of sunflower improved by the application of FYM with N in two experiments. Mahrous *et al.* (2014) the obtained results showed that, there were no significant effect of the interaction between the varieties and various form of fertilizers (organic, bio and mineral) application in most of the studied traits except in seed oil content of sunflower.

Protein content ranged from 18.9 to 33.9% (Table 5.10). The highest protein content (33.9%) in seed was found in the treatment, 5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} could be attributed to higher nitrogen content in seed (4.46%) as compared to 3.17% in the control. The results showed that protein content increased with the increasing rate of NPK fertilizers and rice bran. Results, further, showed that increase in protein content with the increase of sole RB, sole NPK fertilizers was not significantly (P<0.05%) different but different combinations of NPK fertilizers and rice bran increased the same significantly (P<0.05%) over the control (Table 5.10). The treatments may be arranged, in the order of 12>13>14>15>11>9>10>16 >8>7>6> 5>4>3>2>1, so far protein content is concerned.

These findings agreed well with Bader and Qureshi (2014) who reported that decomposted rice husk improved total carbohydrate and protein contents of sunflower which may be due to improvement in availability in nitrogen in soil. Similar information was also put forwarded by Mahrous *et al.* (2014) and Shoghi-Kalkhoran *et al.* (2013).

8.3.3 Influence of NPK and poultry litter

Results showed that increase in oil content of seed increased significantly (P<0.05%) with the increase of NPK fertilizers and poultry litter in some cases. Highest dose of NPK and poultry litter showed lowest oil content (37.7%) in sunflower seed. The oil content ranged between 37.7 and 47.7% (Table 6.10). The highest oil content (47.7) was observed in the treatment, 3t PL ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. The lowest oil content was observed in the highest combination of NPK fertilizers and poultry litter, 4.5t PL ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}. On the basis of oil content, the treatments may be arranged in the order of 12>13>10>4 >2>14>15> 6>9>2>1>8>11>7>5>16.

These observations are in well agreement with the findings of Karim *et al.* (2013) who reported that treatment of poultry litter significantly influenced oil content of BINA soybean-2. Similarly, Oshundiya *et al.* (2014) reported that oil contents of seed from early and late sown sunflower plants increased significantly (P< 0.05) due to organic fertilizer application. Munir (2007) also reported that all the seed quality traits of sunflower were found significantly different due to application of various combinations of poultry manure and inorganic fertilizers. Buriro, *et al.* (2015) who reported that oil content of sunflower was significantly ($P<0.05$) affected by conjunctive use of different organic manures and inorganic NPK fertilizers. Similar information was put forwarded by Abbas *et al*. (2013) in sunflower.

Protein content ranged from 18.0 to 31.8%. The highest protein content (31.8%) was found in the treatment, 3t PL $ha^{-1}+N_{120}P_{90}K_{150}kg\ ha^{-1}$ and could be attribute to higher nitrogen content in seed (5.18%) compared to control (2.89%) in Table 6.10. The lowest protein content (18.0%) was found in the control due to lower nitrogen content in seed (2.89%). The results showed that protein content increased with the increasing rate of NPK fertilizers and poultry litter in most of the cases. On the basis of protein content, the treatments could be arranged in the order of 13>10>12>15>14>16>9>11>8>4>3>2>6> 7>5 >1.

These observations are in good agreement with the findings of Esmaeilian *et al.* (2011) who reported that sheep manure and poultry manure applied yielded statistically superior percentage of protein and protein yield. Karim *et al.* (2013) reported that applied poultry litter significantly influenced the protein content of BINA soybean-2. Amujoyegbe and Alofe (2003) also reported that the crude protein of cowpea was clearly highest with poultry manure and inorganic fertilizer. Similarly, Munir (2007) also reported that all the seed quality traits of sunflower were significantly different due to treatment of various combinations of poultry manure and inorganic fertilizers. Anguria *et al*. (2017) also reported that poultry manure plus finger millet husks (3t ha^{-1}) enhanced protein content of sesame seed.

8.3.4 Influence of NPK and vermicompost

Results of oil content showed an increase with the increase of application of NPK fertilizers and vermicompost (Table 7.10). The oil content varied between 29.7 and 46.9%. The highest oil content (46.9%) was observed in the treatment, 7.5t VC $ha^{-1}+N_{80}P_{60}K_{100}kg\ ha^{-1}$. The lowest oil content was measured in the treatment, $N_{120}P_{90}K_{150}kg\ ha^{-1}$, which was yielded from the highest dose of NPK fertilizers (Table 7.10). On the basis of oil content, the treatments may be arranged in the order of15>13>10>12>8>16>1>14>4>6>3>2>9>11>5> 7.

These observations are in good agreement with the observations of Godavari *et al.* (2017) who reported that application of 100 per cent RDF with vermicompost @ 2.5 t ha^{-1} recorded the highest oil yield except oil content of sunflower which was at par with each other. Rakesh *et al.* (2013) found that oil content (%) in the four treatments such as VC @ 5t ha^{-1}, 10t ha^{-1}, 20t ha^{-1} and NPK (RDF) showed a significant increase of 1.0, 1.1, 1.2 and 1.25% respectively, as compared to control (0.97%) in wheat (*Triticum aestivum* L).

Protein content ranged between 17.4 and 31.0% due to treatments of NPK and VC. The highest protein content (31.0%) was found in the treatment, 5t VC ha^{-1} +$N_{120}P_{90}K_{150}$kg ha^{-1} could be attributed to higher nitrogen content in seed (4.45%) compared to (2.80%) control (Table 7.10). Results also showed that protein content increased with the increasing rate of NPK fertilizers and vermicompost in most of the cases. On the basis of protein content, the treatments may be arranged in the order of 13>10>16>12>15>7>11>6>14>9>4> 3>5>2>8>1.

These results are in well agreement with the reports of Oshundiya *et al.* (2014) who reported that protein contents of seeds from early sown sunflower plants were significantly ($P< 0.05$) increased by organic fertilizer application. Patil *et al.* (2008) who recorded the highest amounts of crude protein and protein content in soybean by conjoint use of manures and fertilizers. Joshi *et al.* (2013), further, reported that all the qualities of wheat grain treated with vermicompost varied significantly from control although differences within various vermicompost treatments were found to be not significant.

From the results of above four experiments, it became evident that integrated treatments enhanced the seed quality of sunflower as compared to sole application of NPK and organic manures.

8.4 Effects of NPK and organic manures on benefit: cost ratio of sunflower

Benefit: cost ratio is the most important factor to any crop cultivation. If a farmer wants to earn handsome profit for long time from his farm, he must ensure balance benefit: cost ratio and maintaining soil health and preventing environmental hazards.

8.4.1 Effects of NPK and cow dung

Cost and return analysis ratio increased with the increasing rates of CD and NPK alone and in combinations over the control treatments in all the cases (Table 4.11). The highest benefit: cost ratio was obtained (3.62) in the treatment, 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}. The second highest value (3.61) was recorded in the treatment, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. Integrated treatments of NPK fertilizers and cow dung contributed higher B: C ratio as compared to alone application of either NPK fertilizers or cow dung. Results indicate that the treatment, 7.5t CD ha^{-1}+$N_{40}P_{30}$ K_{50}kg ha^{-1}, is optimum for sunflower cultivation to get good return. On the basis of B:C ratio, the treatments were arranged in the order of 14>15>6>13> 12>8>16>9>11>7>10>5>4>2>3>1.

These findings are in agreement with Ramulu (2009) who revealed that application of 100 per cent RDF (62.5: 75: 62.5) kg NPK ha^{-1} +7.5 t FYM ha^{-1} in sunflower showed higher B: C ratio (3.00) as compared to only FYM at 7.5 t ha^{-1} (2.41). Naveen (2009) observed that in sunflower cultivation net return (Rs.15285) and B: C ratios (2.09) were found maximum with FYM 10 t + bio-digester liquid manure (CD) equivalent to 30 kg N ha^{-1}. Application of FYM at 10 t ha^{-1}+bio-digester liquid manure (CD) equivalent to 30 kg N ha^{-1} recorded higher B: C ratio (2.09) compared to FYM at 7.5 t + 25: 50: 25 kg NPK ha^{-1} (1.69) in groundnut (Reddy *et al*., 2010; Suresh Naik, 2011).

8.4.2 Effects of NPK and rice bran

Increasing rates of rice bran and NPK alone and in their combinations increased the B: C ratio in all the cases over the control (Table 5.11). The higher benefit: cost ratio was obtained (2.51) in 7.5t RB ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} treatment. The second highest value (2.48) was recorded in the treatment, 2.5t RB ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}. Integrated treatments of NPK fertilizers and rice bran contributed higher B: C as compared to application of either NPK fertilizers or rice bran alone. Results indicate that 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, is the optimum dose for cultivation of sunflower to get better return. On the basis of B: C ratio, the treatments were arranged in the order of 15>8>10>9>11> 6>14>13>7>5>12>4>16>3> 2>1.

These observations are in agreement with the findings of Khatik and Dikshit (2001) who revealed that the highest net return (Rs.7461. ha^{-1}) and C: B ratio (1:2.17) resulted from the plant treated with NPK+ compost at 10 tones ha^{-1}. Similarly, Basavaraju and Purushotham (2009) reported that 50 per cent N through FYM +50 per cent NPK through fertilizer in finger millet recorded higher B: C ratio (2.03), as compared to recommended N with available P and K through vermicompost (B: C ratio 1.08).

8.4.3 Effects of NPK and poultry litter

Cost and return analysis ratio increased with the increasing levels of poultry litter and NPK alone and in their combinations in most of the cases except in the treatment, 4.5t PL ha^{-1} (Table 6.11). The highest benefit: cost ratio was recorded (2.58) in 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} treatment. The second highest value (2.52) was measured in the combination of 3t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1}. Combined treatments of NPK fertilizers and poultry litter contributed higher B: C ratio as compared to single application of either NPK fertilizers or poultry litter. Results indicate that 4.5t PL ha^{-1}+N_{40} $P_{30}K_{50}$kg ha^{-1} is optimum for sunflower cultivation to get higher return. On the basis of B:C ratio, the treatments were arranged in the order of 14>11>13>7>9>12>10>15>16>8>6>2>3>5> 4>1.

These observations are in agreement with the findings of Hammad *et al.* (2011) who revealed that the combination of GM+PL+SS each @ of 10 t ha^{-1} showed maximum economic yield (3.65 t ha^{-1}), attaining the B: C ratio of 1: 1.37 in wheat. Tejeswara Rao *et al.* (2013) reported that among the organic sources tried, the highest net returns and benefit-cost ratio of sunflower were realized with poultry manure in combination with *Panchagavya*. Agbede *et al.* (2017) reported that application of 20 t ha^{-1} poultry manure showed the best carrot productivity as indicated by higher benefit-to-cost ratio.

8.4.4 Effects of NPK and vermicompost

Analysis of cost and return ratio increased with the increasing doses of vermicompost and NPK fertilizers applied alone and in their combinations (Table 7.11). The highest dose of NPK fertilizers and vermicompost showed comparatively lower benefit: cost ratio that belong to the treatment, 7.5t VC ha^{-1}+$N_{120}P_{90}K_{150}$ kg ha^{-1}. The higher benefit: cost ratio was obtained (3.35) in the treatment, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}. The second highest value of B: C ratio (3.02) was recorded in the treatment, 5t VC ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}. NPK fertilizers and vermicompost together contributed generally higher B: C ratio as compared to alone applications of either NPK fertilizers or vermicompost. Results indicate that the treatment, 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} is the optimum dose for higher return of sunflower. On the basis of B:C ratio, the treatments were arranged in the order of 12>13>10>14>15>11>9>6>8> 7>16>5>3>4>2>1.

These observations are in well agreement with the observations of Godavari *et al*. (2017) who reported that highest gross (Rs. 42266 ha^{-1}), net monetary returns (Rs. 24475 ha^{-1}) and B: C ratio (2.38) of sunflower was recorded in RDF + vermicompost @ 2.5t ha^{-1} followed by application of 100% RDF with hydrogel. Byrareddy *et al*. (2008) also reported that the maximum benefit: cost ratio was realized with the application of RDF + FYM 8 t ha^{-1} (5.9) followed by 50 per cent N (11t ha^{-1} VC) + 50 per cent (urea) +64.50 kg ha^{-1} P_2O_5 (SSP) (5.8), while the least B: C ratio was recorded from sunflower grown in controlled condition (1.7). Similarly, Tejeswara Rao *et al.* (2013) reported that gross returns as well as net returns of sunflower were measured at their best with recommended dose of fertilizer either with or without *Panchagavya* spray.

8.5 Comparison of organic manures used

Comparison of treatments sequential studies showed that application of rice bran produced the highest yield of dry matter in sunflower plant in sequences l and ll i.e. in cases of exclusion of main effects of NPK and organic manures (Table 8.1). Rice bran and poultry litter became almost equally effective in production of biomass when all the treatments were included in sequence lll.

However, the trend has been changed in case of yields of seed and oil of sunflower in all the sequences of treatments applied to the plant (Table 8.1). The treatment of cow dung recorded the best performance in yields of seed and oil in all the sequences. Treatment sequences revealed that poultry litter played the least role in the production of seed and oil of sunflower seed.

Table 8.1 Sequence of treatment performance following portioning of yield attributes of sunflower

Yield attributes	Sequences	Performance order
Dry matter	I	RB (5.06) > PL (4.92) > VC (4.70) ≥ CD (4.68)
(kg plot^{-1})	II	RB (5.90) > PL (5.57) > CD (5.32) ≥ VC (5.29)
	III	PL (5.04) ≥ RB (5.03) > VC (4.95) > CD (4.53)
Seed	I	CD (2.32) > VC(2.02) > RB (1.73) = PL (1.73)
(kg plot^{-1})	II	CD (3.22) > VC(2.37) > PL (2.02) ≥ RB (1.99)
	III	CD (2.25) > VC (1.93) > RB (1.72) > PL (1.68)
Oil	I	CD (1.02) > RB (0.84) = VC (0.84) > PL (0.76)
(kg plot^{-1})	II	CD (1.17) > VC (1.00) > PL (0.89) ≥ RB (0.87)
	III	CD (0.99) > RB (0.82) > VC (0.78) > PL (0.73)

Note: l = Excluding main effects of NPK; ll = Excluding main effects of NPK and organic manures; lll = Including NPK and organic manures.

Table 8.2 Ranking of organic manures in sunflower production

Yield attributes	Maximum	Intermediate	Minimum
Dry matter	RB	PL, VC	CD
Seed	CD	RB, VC	PL
Oil	CD	RB, VC	PL

So, the overall assessment of the effects of organic manures reflects that RB is the best for production of dry matter of sunflower plant. However, CD appeared to be the best for seed and oil production (Table 8.2). Comparatively CD played the least role in dry matter accumulation and that for seed and oil is PL. However, intermediate role was played by PL for dry matter yield and that for both seed and oil yields is RB. VC always recorded the intermediate role in case of all the attributes of yield of dry matter, seed and oil.

CHAPTER 9

Summary, Conclusions and Recommendation

Impact of CD (0.0, 2.5, 5.0, 7.5 t ha^{-1}), RB (0.0, 2.5, 5.0, 7.5 t ha^{-1}), PL (0.0, 1.5, 3.0, 4.5 t ha^{-1}) and VC (0.0, 2.5, 5.0, 7.5 t ha^{-1}); and NPK (0.0, 50, 100, 150%) alone and in combination on the growth, yield and nutrient content of sunflower have been summarized in this section.

Growth of sunflower plant

The growth of the sunflower have been expressed in terms of plant height, number of leaf, leaf area and leaf area index and the results were summarized steps wise.

NPK fertilizers and cow dung

The highest plant height (208.4cm), number of leaf (41.2 $plant^{-1}$), leaf area (410.5cm^2) and leaf area index (12.75) were observed in the treatments, 7.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1}, 2.5t CD ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} and 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} respectively (Tables 4.1- 4.2).

NPK fertilizers and rice bran

The highest plant height (196.0cm), number of leaf (45.5$plant^{-1}$), leaf area (384.4cm^2) and leaf area index (13.6) were recorded in the treatments, 7.5t RB ha^{-1}+ $N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t RB ha^{-1}+ $N_{120}P_{90}K_{150}$kg ha^{-1} respectively (Tables 5.1- 5.2).

NPK fertilizers and poultry litter

The highest plant height (204.3cm), number of leaf (44.6$plant^{-1}$), leaf area (376.4cm^2) and leaf area index (13.61), respectively, were found in the treatment, 4.5t PL ha^{-1}+ N_{120} $P_{90}K_{150}$kg ha^{-1} (Tables 6.1- 6.2).

NPK fertilizers and vermicompost

The highest plant height (198.4cm), number of leaf (45.3$plant^{-1}$), leaf area (381.0cm^2) and leaf area index (14.62) were found in the treatments, 7.5t VC ha^{-1}+ N_{80} $P_{60}K_{100}$kg ha^{-1} and 7.5t VC ha^{-1}+ N_{120} $P_{90}K_{150}$kg ha^{-1}, respectively, at maturity of sunflower plant (Tables 7.1- 7.2).

Yield and yield components of dry matter

The dry matter of stem, root, leaf, petiole, inflorescence and yield of total dry matter were summarized as follows.

NPK and cow dung

The highest dry weight of stem, root, leaf, petiole, inflorescence and total dry matter production were found to be 60.67, 12.83, 25.33, 10.00, 19.33 and 121.34 g plant^{-1} or 6.3t ha^{-1}, respectively, in 7.5t CD ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment (Table 4.3).

NPK and rice bran

The highest dry weight of stem, root, leaf, petiole, inflorescence and total dry matter production were recorded to be 67.3, 16.0, 24.0, 5.8, 18.0 and 127.7 g plant^{-1} or 6.6t ha^{-1}, respectively, in 7.5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment (Table 5.3).

NPK and poultry litter

The highest dry weight of stem, root, leaf, petiole, inflorescence and total dry matter production were found to be 63.82, 12.66, 21.47, 8.7, 32.6 and 134.0 g plant^{-1} or 7.0t ha^{-1}, respectively, in 4.5t PL ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} treatment (Table 6.3).

NPK and vermicompost

The highest dry weight of stem, root, leaf, petiole, inflorescence and total dry matter production were found to be 72.4, 18.87, 16.7, 7.7, 38.3 and 153.9 g plant^{-1} or 7.99t ha^{-1}, respectively, in $N_{120}P_{90}K_{150}$kg ha^{-1} treatment (Table 7.3).

The data showed that the dry matter production of different organs of sunflower plant were generally better in the VC treated plants, NPK imparting its best performance up to their highest dose alone. However, it produced lowest oil content. It means that highest dose of NPK without manures produced lowest seed yield and oil content.

Seed and yield components

The diameter of inflorescence (cm), weight of seeds (g plant^{-1}) and number of seeds (plant^{-1}) were summarized.

The highest diameter of inflorescence was found 52.67, 52.7, 54.0 and 62.3 cm, respectively, in treatments, (5t CD ha^{-1}+N_{120} P_{90} K_{150}kg ha^{-1}), (5t RB ha^{-1}+N_{120} P_{90} K_{150}kg ha^{-1}), (3t PL ha^{-1}+N_{120} P_{90} K_{150}kg ha^{-1}) and (5t VC ha^{-1}+N_{120} P_{90} K_{150}kg ha^{-1}) respectively (Tables 4.3, 5.3, 6.3, 7.3). These findings indicate that application of highest dose of NPK fertilizers and medium dose of organic manures generally showed better performance.

The highest weight of dry seeds plant^{-1} was found 64.7, 46.0, 44.4 and 57.61 g plant^{-1} respectively. The highest seed yield (g plant^{-1}) was produced in the treatments, 7.5t CD ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and those of poultry litter and vermicompost were observed in 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1} and 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} treatments respectively (Tables 4.3, 5.3, 6.3, 7.3). The highest number of seeds was found to be 735.7, 638.9, 663.0 and 676.7 plant^{-1} in CD, RB, PL and VC treated plants respectively (Tables 4.3, 5.3, 6.3, 7.3). In cow dung and vermicompost treated experiments, number of seed was observed to be the highest in the treatments, 5t CD ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1} and those of rice bran and poultry litter were showed in the treatments, 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1} and 4.5t PL ha^{-1} +$N_{40}P_{30}K_{50}$kg ha^{-1} respectively. The, overall, highest number of seeds (735.7 plant^{-1}) was found in the treatment, 5t CD ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}.

Concentration and uptake of NPKS in different organs of sunflower plant

The concentration and uptake of NPKS of stem, root, leaf, petiole, inflorescence and seed were summarized.

The highest concentrations of NPKS in stem were found in the treatments, 13 in most of cases (Tables 4.4, 5.4, 6.4, 7.4). Generally, the highest concentrations of N (1.33%), P (0.42%), K (1.95%) and S (0.19%) were found in the experiments CD for N and S, PL for P and VC for K respectively.

The highest uptakes of NPKS in stem were found in the treatments, 13, 16, 15 and 7 respectively (Tables 4.4, 5.4, 6.4, 7.4). These findings indicate that application of the highest and medium doses of NPK fertilizers and organic manures produced better results. The highest uptakes of N (787.4mg plant^{-1}), P (256.6 mg plant^{-1}), K (999.6mg plant^{-1}) and S (111.7mg plant^{-1}) were found in RB for N and S, PL for P and VC for K respectively.

The highest concentrations of NPKS in root were found in the treatment, 13 in most of the cases (Tables 4.5, 5.5, 6.5, 7.5). The highest concentrations of N (1.08%), P (0.54%), K (2.66%) and S (0.20%) were found in plants treated with CD for N, PL for P and VC for K and S, respectively, in root. The highest uptakes of NPKS in root were found in the treatment, 13, 16 and 15 respectively (Tables 4.5, 5.5, 6.5, 7.5). Similarly, the highest uptakes of N (187.2mg plant^{-1}), P (64.6mg plant^{-1}), K (344.0mg plant^{-1}) and S (23.8mg plant^{-1}) were found in plants treated with RB for N and K, PL for P and VC for S, respectively, in root.

The highest concentrations of NPKS in leaf were found in the treatment, 13 and 16 respectively (Tables 4.6, 5.6, 6.6 and 7.6). The highest concentrations of N (4.47%), P (0.67%), K (4.28%) and S (0.24%) were found in plant treated with PL for N, CD for P and RB for K and S, respectively, in leaf. The highest uptakes of NPKS in leaf were found in the treatment, 13, 14 and 16 respectively (Tables 4.6, 5.6, 6.6, 7.6). The highest uptakes of N (903.5mg plant^{-1}), P (129.5mg plant^{-1}), K (971.6mg plant^{-1}) and S (55.2mg plant^{-1}) were found in plants treated with CD for P and RB for N, K and S, respectively, in leaf. These findings indicate that application of the highest dose of NPK fertilizers and medium dose organic manures generally produced better result.

The highest concentrations and uptakes of NPKS in petiole and inflorescence were found in 7.5t CD ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1}, 7.5t RB ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1}, 4.5t PL ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1} and 7.5t VC ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1} treatments respectively (Tables 4.7-4.8, 5.7-5.8, 6.7-6.8, 7.6-7.8). Overall, the highest concentrations of N (2.60%), P (0.65%), K (3.20%) and S (0.32%) were found in plants treated with PL for N, K and S and RB and VC for P, respectively, in petiole. However, the highest uptakes of N (226.2mg plant^{-1}), P (62.0mg plant^{-1}), K (300.0mg plant^{-1}) and S (22.0mg plant^{-1}) in petiole were recorded in the plants supplied with PL for N and CD for P, K and S respectively.

The maximum concentrations of N (2.16%), P (0.95%), K (2.25%) and S (0.32%) in inflorescence were accounted in the plants provided with RB for N, PL for P and S, and CD for K respectively. Similarly, the highest uptakes of N (384.8mg plant^{-1}), P (281.2mg plant^{-1}), K (678.5mg plant^{-1}) and S (94.7mg plant^{-1}) in inflorescence were found in PL for N, P and S and VC for K respectively (Tables 4.7-4.8, 5.7-5.8, 6.7-6.8, 7.6-7.8). These findings indicate that application of the highest doses of NPK fertilizers and organic manures produced better results.

The highest concentrations of NPKS in seed were found in the treatments, 13, 15 and 16 respectively (Tables 4.9, 5.9, 6.9, 7.9). The highest concentrations of N (5.24%), P (0.94%), K (1.08%) and S (0.47%) were found in sunflower seeds treated with different organic manures i.e. RB for N and S, CD for P and VC for K respectively. The maximum uptakes of NPKS in seed were found in 13 and 15 treatments respectively (Tables 4.9, 5.9, 6.9, 7.9). The highest uptakes of N (3115.0mg plant^{-1}), P (601.7mg plant^{-1}), K (571.0mg plant^{-1}) and S (128.5mg plant^{-1}) were found in sunflower seeds fertilized with different manures i.e. CD for N and P, VC for K and PL for S respectively. Application of the highest and medium doses of NPK fertilizers and organic manures generally produced better result.

Quality parameters of sunflower seeds

The highest weight of 100 seeds were found 9.80, 7.30, 7.40 and 7.53g in the treatments of 7.5t CD ha^{-1}+ $N_{80}P_{60}$ K_{100}kg ha^{-1}, 5t RB ha^{-1}+ $N_{80}P_{60}$ K_{100}kg ha^{-1}, 3t PL ha^{-1} +$N_{120}P_{90}$ K_{150}kg ha^{-1} and 7.5t VC ha^{-1}+ $N_{120}P_{90}$ K_{150}kg ha^{-1} respectively (Tables 4.10, 5.10, 6.10, 7.10). The results showed that application of the highest and medium doses of NPK fertilizers and organic manures, respectively, produced better yields. The, overall, best yield of 100 seed (9.80g) was found in CD and NPK treated plant. The highest oil contents extracted were 51.8, 51.1, 47.7 and 46.9% in the seed treated with 5t CD ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1}, 5t RB ha^{-1}+$N_{120}P_{90}K_{150}$kg ha^{-1}, 3t PL ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1} and 7.5t VC ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1} respectively (Tables 4.10, 5.10, 6.10, 7.10). However, the best yield of oil (51.8%) produced in seed collected from CD and NPK treated plant. The highest protein content evaluated were 30.2, 33.9, 31.8 and 31.0% in the seed fertilized with 5t CD ha^{-1}+ $N_{120}P_{90}$ K_{150}kg ha^{-1}, 5t RB ha^{-1} +$N_{80}P_{60}$ K_{100}kg ha^{-1}, 3t PL ha^{-1}+ $N_{120}P_{90}$ K_{150}kg ha^{-1} and 5t VC ha^{-1}+$N_{120}P_{90}$ K_{150}kg ha^{-1} respectively (Tables 4.10, 5.10, 6.10, 7.10). These suggest that application of the highest and medium doses of NPK fertilizers and medium dose of organic manures produced generally better yield of oil and protein. The best yields of oil (51.8%) and protein (33.9%) were evaluated with NPK fertilizers applied separately with CD and RB respectively.

The highest benefit: cost ratios were counted 3.62, 2.51, 2.58 and 3.35 in the treatments of 7.5t CD ha^{-1}+$N_{40}P_{30}$ K_{50}kg ha^{-1}, 7.5t RB ha^{-1}+ $N_{80}P_{60}$ K_{100}kg ha^{-1}, 4.5t CD ha^{-1}+N_{40} P_{30} K_{50}kg ha^{-1} and 5t VC ha^{-1}+$N_{80}P_{60}$ K_{100}kg ha^{-1} respectively (Tables 4.11, 5.11, 6.11, 7.11). Application of medium and minimum doses of NPK fertilizers and highest and medium dose of organic manures were found to be the best return.

Conclusions

From the observation of the experiments the following conclusions can be drawn:

i. In vermicompost, poultry litter, rice bran and cow dung treated experiments, plant height, leaf number, leaf area, leaf area index and dry matter were found highest at maturity in the treatment, 16 in most of the cases.

ii. In rice bran and cow dung treated experiments, seed yield was observed the highest in the treatment, 15 and those in vermicompost and poultry litter were in treatment, 12.

iii. In all the four experiments, concentration and uptake of NPKS were observed maximum in the treatments, 13 and 16 respectively.

iv. In cow dung and rice bran treated experiment, the highest % of oil was observed in the treatment 13 and those in vermicompost and poultry litter were in treatments, 15 and 12 respectively.

v. The highest % of protein was found in the treatment, 13 in most of the cases, except rice bran in treatment, 12.

vi. In cow dung and poultry litter treated experiments, the highest B: C ratios were found in treatment, 14 but vermicompost and rice bran were in treatments, 12 and 15, respectively, in this respects.

Recommendation

On summarization of the results, the following recommendations may be suggested on the basis of best yield of sunflower and the highest B: C ratios.

i. The economic doses are as follows:

a. 7.5t CD ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}, (CD_{14})

b. 7.5t RB ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, (RB_{15})

c. 4.5t PL ha^{-1}+$N_{40}P_{30}K_{50}$kg ha^{-1}, (PL_{14})

d. 5t VC ha^{-1}+$N_{80}P_{60}K_{100}$kg ha^{-1}, (VC_{12})

ii. Organic manure stimulated the growth, yield and quality of sunflower plant with intensity of doses.

iii. Proper application of organic manure reduced the application of inorganic fertilizer in sunflower cultivation.

iv. Organic farming positively increased oil content of the sunflower plant.

v. Efforts may be given to make the farmers aware of the appropriate fertilizer management practices.

vi. Future research activities may be undertaken to be sure of the applied doses (organic + inorganic) fertilizers application to increase yield per unit area of land.

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