EFFECT OF ORGANIC AND INORGANIC NITROGEN SOURCES ON GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER GROWN IN HIGHLY WEATHERED SOILS OF MOROGORO

By

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DECLARATION

DECLARATION

This Thesis is my original work and has not been presented for an award of a degree in any other university.

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DEDICATION

This work is dedicated to my parents Almasi M. Irika and my beloved late mother Mwajuma R. Mukiya, as they laid down a base of my education; and to my sisters Hawa and Safina for their encouragement throughout my studies.

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ABSTRACT

Sunflower contributes about 40% of total national cooking oil requirement in Tanzania, ranking as one of the most important cooking oil with very high nutritional value. However, its production per unit area ranges between 800 and 1100 kg/ha, the average of which is below the potential production of 1200 to 2000 kg/ha in most African countries. The low sunflower productivity is partly attributed to low soil fertility. A field experiment was therefore conducted during the 2013/2014 long and short rains season at the Sokoine University of Agriculture soil science experimental sites to determine the effect of fertilizers; farmyard manure (FYM) and inorganic nitrogen fertilizers on sunflower growth, yield and seed oil content. The treatments consisted of: control (no nitrogen fertiliser, no farmyard manure); 2 t farmyard manure (FYM)/ha applied at planting; 5 t FYM/ha applied at planting; 10 t FYM/ha at planting; 20 kg N/ha applied as UREA at 30 days after planting; 40 kg N/ha applied as UREA at 30 days after planting; 60 kg N/ha applied as UREA at 30 days after planting; 2 t FYM/ha at planting + 20 kg N/ha applied as UREA at 30 days after planting; 5 t FYM/ha at planting + 40 kg N/ha applied as UREA at 30 days after planting and 10 t FYM/ha applied at planting + 60 kg N/ha applied as UREA at 30 days after planting. The treatments were laid out in a randomized complete block design and replicated three times. Sunflower variety *record* was used as a test variety. Data collected included: plant height and number of leaves at 15, 30, 45, 60 and 75 days after planting (DAP); Head diameter, biomass yield, total seed yield per hectare, weight of 1000 seeds, seed oil content and total seed oil yield per hactare. All data were subjected to analysis of variance (ANOVA) using General Statistical Package (GENSTAT) and means were separated using the least significant difference (LSD) test at P = 0.05.

The results showed that plots supplied with farmyard manure alone or in combination with inorganic N- fertilizers had significantly taller sunflower plants than the no fertilizer control plots. Application of FYM at the rate of 10 t/ha increased plant height, biomass formation, and oil content. The application of 10 t FYM/ha and 60 kg N/ha significantly increased seed yield and weight of 1000 seeds. Application of 60 kg N/ha increased plant height at 60 days after planting during the long rains season and number of leaves at 45 DAP and 60 DAP in both seasons of the experiment. Application of inorganic nitrogen fertilizers at rates lower than 60 kg N/ha did not significantly increase sunflower crop performance relative to control.

It was concluded that application of fertilizers had positive impacts on crop growth, yield, yield components and percentage oil content as of sunflower. However unlike the other parameters, oil content was only increased by 10 t FYM/ha and control had higher oil content than some other treatments in both seasons. The evidence from crop performance in terms of height, head diameter, yield and yield components suggested that a combination of FYM and inorganic nitrogen fertilizers at rates of 40 kg N /ha + 5 t FYM/ha and 60 kg N /ha +10 t FYM/ha are the most promising soil fertility management practice followed by FYM alone especially to small scale farmers who cannot afford the high costs of inorganic fertilizers. It was also concluded that application of inorganic nitrogen fertilizers at rates 20 kg N/ha and 40 kg N/ha showed no significant effect on sunflower crop yields.

It was therefore recommended that farmers in Morogoro to consider application of fertilizers in sunflower crop production, especially 10 t FYM/ha alone and/or combination of 60 kg N/ha + 10 t FYM/ha as an important farm management practice to obtain seed yield of more than 1 t/ha.

CHAPTER 1:INTRODUCTION

1.1 Background

Agriculture is the back bone of the economy of Tanzania. It employs about 80% of Tanzania's population which lives in rural areas and directly depends on agriculture and natural resources for their livelihoods (URT, 2008). Cash crops in Tanzania play a great role in improving farmers' livelihoods. The crops range from fiber (sisal and cotton), beverages (tea and coffee) as well as oilseed crops (sunflower, sesame and groundnuts)

Sunflower is one of the oilseed cash crops which have been promoted by the government and private sectors as a potential crop for improving farmers' livelihoods and ensuring availability of healthy edible oil in the country (RLDC, 2010). However, the crop is still facing low production and productivity challenges which might partly be attributed to poor soil fertility, low use of improved seeds and poor agronomic practices. Turuka *et al*., 2001 reported that, of all farm management and farm input applications inorganic fertilizers alone increases yields by 35 to 40 % followed by improved seeds. Application of nitrogen fertilizers and farm yard manure has a great impact on sunflower growth, biological yield components as well as oil content Helmy and Ramdan, (2009).

Sunflower (*Helianthus annuus* L.) is an annual erect broadleaf oil crop with a strong tap root system. It is grown all over the world. It is one of the few crops that originated from North America. The leading countries in production being areas of Soviet Union, Argentina, Eastern Europe, US, China, France and Spain. Apart from sunflower being a good oil crop it can also be a good source of snack seeds as well as animal feeds (sunflower oil seed cakes and crop silage). The crop is suited to wide range of agro ecological zones with wide range of temperatures, soil types and rainfall patterns. It ranks the third most important source of edible oil in the world after soya bean (*Glycine max* L.) and cotton (*Gossypium hirsutum* L.) (Berglund *et al*., 2007).

In Tanzania sunflower was introduced during colonial times of 18th century and it grows in almost all parts of the country. The main sunflower growing regions in Tanzania include: Singida, Rukwa, Dodoma, Iringa, Manyara, Mbeya, Morogoro and Shinyanga. The crop gained popularity about less than 15 years ago after increased peoples' awareness of its healthier oil free of cholesterol and rich in polyunsaturated fatty acids than other vegetable oils (Ugulumu, 2007). Other oil crops competing with sunflower in the country are groundnuts 40%, sesame 15%, cotton 8%, and palm oil 1%. (RLCD, 2008). Sunflower subsector is one of the key sectors in the agriculture industry. It contributes about 40% of total national cooking oil requirement, ranking as one of the most important cooking oils with very high value (ARI- Ilonga, 2008).

A number of studies have been done on sunflower production and the associated factors affecting the global, regional and national production levels. One of the limiting factors in sunflower production among majority of Tanzanian farmers is poor soil fertility and productivity. For instance Berglund (2012) reported that low sunflower yields can be caused by incorrect plant population, poor soil fertility, lack of weed control, diseases, insect damage, bird depredation, lodging, late planting and harvesting losses. Oyinlola *et al*., (2010) also noted that nitrogen deficiency is generally the most limiting nutritional disorder which affects sunflower production in the study on "response of sunflower to nitrogen application" in Nigeria. Similarly Warrick, (2001) reported in literature from the sunflower production guide for west central Texas that in order for farmers to obtain high and consistent sunflower yields, an adequate fertilizer programme should be part of production planning . Helmy and Ramdan, (2009) also noted that use of animal wastes and nitrogen fertilizer contribute significantly in increasing sunflower seed yields and oil content from his study on agronomic performance and chemical response of sunflower to some organic nitrogen sources and conventional sunflower fertilizers under sandy soil conditions in Egypt. This signifies that, soil fertility management is essential for consistent achievement of high sunflower seed yields and high oil content.

1.2 Statement of the Problem and Justification

The conventional method of sunflower production in many parts of Tanzania and Africa is cultivation without considering the soil fertility management practices. This leads to poor plants growth and low yields in return. In addition, farmers rely mostly on extensive cultivation to increase crop yields, the practice which leads to deforestation and soil fertility depletion. Production of sunflower oil seed in Tanzania has been increasing from 75,000 tons to 100,000 tons from 2002 to 2005, the production then increased dramatically to 350,000tons in 2007. The main reason for this increase is due to opening up of new land under sunflower production and a bit of use of improved seeds (MAFC, 2009). This accounts for extensive cultivation rather than intensively agricultural production where farmers open up a virgin land, cultivate for three to four consecutive years and abandon the farms after depleting the soils.

Further, it is estimated that 350,000 tons of oil seed produced 90,000tons of sunflower oil per year. FAO recommends annual per capita oil consumption of 5 kg of vegetable oil. In 2002 census the population was 35,000,000 in Tanzania and the equivalent oil demand was 175,000,000 kg. With current Tanzania population of 44,000,000 people, the amount of oil needed is 220,000,000 kg per year. Thus, the demand for vegetable oil is high and the production has not met this demand. Despite continuous increase in area under production, there is still low production per unit area, and the deficit has been compensated by oil importation from Malaysia and Indonesia. To date Tanzania is a net importer of oil. Although there is good production of other oil seeds like groundnuts and sesame, sunflower oil is mostly preferred because of its high quality and healthy oil (free of cholesterol) and has high oil content of about 40%. This makes sunflower the most important cooking oil produced in Tanzania especially in the central corridor of the country. This shows a great need to deliberately increase sunflower production through soil fertilization in order to:

Nitrogen is an important element in all plant life processes and is also a most frequently deficient plant nutrient element than all other elements. It is because nitrogen is very mobile and it is very prone to losses like leaching, denitrification, volatilization and erosion. Addition of nitrogen fertilizers is important in order to meet the nitrogen plant demand (Hofman, 2004). For optimum sunflower production, nitrogen fertilization is also a very crucial soil fertility management practice.

i) Reduce the importation costs of edible oil from abroad because production will be able to meet the growing demand of edible oil.

ii) Improve community health through consuming cholesterol free high quality edible oil as well as improving livelihood of sunflower value chain actors in general and farmers in particular.

Ugulumu (2008) reported that there is low production of sunflower oil seeds per unit area in Tanzania which is far below the potential production of sunflower seeds in Africa. Sunflower yields in Tanzania ranges between 800 to 1100 kg/ha on average while the potential production of the crop should be 1200 to 2000 kg/ha as it is in most African countries. Poor soil fertility is one of the major factors contributing to the poor sunflower production in Tanzania (Ugulumu, 2008).

There is a greater demand of sunflower oil than the local production. Increase in yields and oil content per unit area through the use of organic and inorganic nutrient sources or their combination might increase the production and meet the demand of sunflower oil in the market. This will finally reduce the national costs on edible oil importation as well as improving farmers' livelihood. Limited research work on the use of fertilizers in sunflower production in Tanzania has been done (MAFC, 2009). This study therefore seeks to determine the effect of application of inorganic nitrogen fertilizers and farmyard manure on growth, yield and seed oil content of sunflower.

1.3 Objectives

The overall objective of the study was to contribute to increased sunflower oil seed productivity through the use of nitrogen fertilizers in order to meet the great demand of sunflower oil in the country. The specific objectives of the study were;

i. To assess the influence of varying inorganic nitrogen fertilizer regimes on plant growth, seed yields and oil content of sunflower
ii. To evaluate the effects of varying farmyard manure on growth, yield components and oil content of sunflower
iii. To evaluate the effects of combined nitrogen fertilizer and farmyard manure on growth, yield components and oil content of sunflower.

1.4 Hypotheses

1. Varying rates of inorganic nitrogen fertilizers has no effect on growth, yield components and oil content of sunflower
2. Varying rates of farmyard manure has no effect on growth, yield components and oil content of sunflower
3. Combined nitrogen fertilizer and farmyard manure has no effect on growth, yield components and oil content of sunflower.

1.5 Scope of the work

The conceptual frame work of this study is based on the assumption that increase in sunflower oil seed production is influenced by good agronomic practices particularly the use of nitrogen fertilizers and farmyard manure in improving soil fertility status. Many studies have shown that addition of nitrogen fertilizers is very important for farmers' to successfully cultivate sunflower in economically sustainable production fashion. Although there are many factors which contribute to low production of sunflower oil seeds, this study will focus on improving the soil fertility and productivity by using inorganic nitrogen fertilizers and organic manure (farmyard manure) in order to meet farmers' yield objectives as well as improved oil availability in the local market.

CHAPTER 2: LITERATURE REVIEW

2.1 Importance of sunflower

Spanish explorers collected sunflower (*Helianthus annuus*. L) from America and by 1950 the plant was an important garden flower in Spain. It has been reported that the origin of wild sunflower varieties originates from North America, but the origin of domestication of the crop has not been known (Habwe 1992). American Indians used a crop as a foodstuff before cultivation of maize. Sunflower then spread as an economic oilseed crop in Russia around 1960s and has found wide acceptance in Europe and mainly produced in the United States of America as an oilseed crop. Sunflower also was used as a medicinal crop, source of dye, oil for ceremonial body painting, pottery and hunting calendar (Berglund et al., 2007).

Expanded world production of sunflower resulted from development of high oil seed varieties by plant scientists through breeding methods and most recently through the development of hybrid seeds (DPP, 2010). In Tanzania sunflower is considered and produced as oil cash crop, employing more than 45% of all farmers in the country and other value chain actors (Ugulumu, 2008). It is grown mainly in areas where maize and rice do not grow well therefore some farmers use cash obtained from sunflower seed or oil sales to buy cereals like maize and rice for food. The crop also fetches higher prices than maize where 1 kg of sunflower at farm gate price was Tsh 300 to Tsh 320 and equivalent weight of maize could be Tsh 150 to Tsh 200 in 2010. Sunflower oil is rich in saturated fatty acids therefore it is in a liquid form at room temperature. This attribute makes the oil free of cholesterol hence healthy for human consumption.

Because of good quality of oil and higher demand in the market, a litre of sunflower oil was sold at Tsh 4,000 per litre while oils from other oilseeds like cotton and groundnuts was sold at Tsh 2500 to Tsh 3,500 per litre (Personal visit at Mwenge local market – Dar es Salaam Aug, 2013). Prices fluctuate depending on the season where immediately after sunflower seeds harvesting period between June to August sunflower oils are plenty in the markets and prices can be as low as Tsh 3,000 per litre, and shoot to Tsh 4,000 per litre between October and May when sunflower supply is low in the local market.

Significant oil seed crops produced in Tanzania include groundnuts (46%), sunflower (36%), sesame (15%), cotton (8%), and palm oil (1%) (RLDC, 2008).

2.2 Current utilization of sunflower seeds

Sunflower seeds are utilized either as oilseeds for pressing cooking oil or confection uses like snack seeds. Sunflower cakes are waste products from oil milling process; the cakes are very rich in proteins and are used as quality feeds for livestock. Oil type sunflower seeds are characterised by small seed size with black hull and high oil content. Confection type sunflower seeds (snack seeds) are larger in size, sweet and have strips.

In Tanzania both classes of seeds are produced but mainly utilized for sole purpose of edible oil production. The main source of planting seeds is indigenous saved seeds. *Record* is the only local seed variety developed for oilseed production. It is an open pollinated sunflower crop variety which is small in size, with black hull and higher oil content than the comparative varieties (Plant Genetic Resources, 2009).

2.3 Sunflower production trend in Tanzania

Sunflower production is mainly dominated by small scale farmers with one to three acres under sunflower production. There are few medium to large scale farmers with more than a thousand acres. RLDC, (2008) reported that in 2006/07 there was average sunflower production of 0.6 tons per hectare and the area under cultivation was estimated to be 600,000 hectare in Tanzania. Generally the production has been increasing and the increase is mainly contributed by opening up of new land under sunflower production. Also around 2006/07 there was production of sunflower using improved varieties which also showed a significant increase in production (RLDC, 2008).

Sunflower oil seeds production in Tanzania 2000-2008.

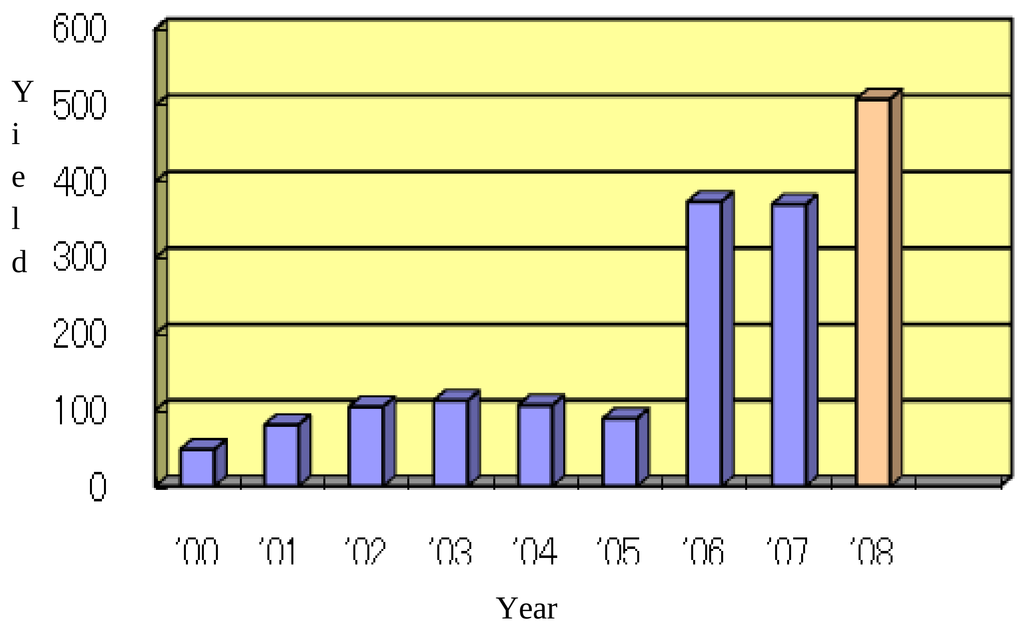

Figure 1: Sunflower oil seed production in Tanzania 2000-2008. '08 showing the highest level. (units in 1000 tons) Source; MITM (2010).

2.3.1 Description of *Record* as a sunflower seed variety

Record is an open pollinated sunflower seed variety which was released in 1950. It is owned and maintained by Tanzania Agricultural Research Institute- Ilonga. The variety is recommended to be produced at places with altitude range of 0 to 2000 meters above sea level and has an optimal grain yield of 1 ton to 2 tons per hectare. In Tanzania the regions falling within this altitude range include Morogoro, Pwani, Dodoma and Singida. It takes 110 to 130 days for *record* variety to mature, 35 to 45 days to 50% flowering and has seed oil content of up to 50%. The variety is susceptible to sunflower rugose mosaic virus and sunflower yellow ringspot (PGR, 2009).

2.4. Nitrogen in sunflower crop

Nitrogen is a major plant nutrient element required by sunflower. It is involved in the structures of all amino acids and proteins as well as many enzymes. It is incorporated in plant organic molecules. It has greatest impact on number of leaves, leaf size, seed size, test weight and yields.

Nitrogen is translocated from lower plant parts to the actively growing upper plant tissues when its concentration in the substrate becomes low. Deficiency symptoms therefore appear on the older leaves and lighter green colour is observed. As symptoms progress the new leaves become small and stem becomes weak, and lower leaves drop off. Death of lower leaves is the severe/advanced nitrogen deficiency symptom (Ray, 1999). This condition leads to serious yield loss as it affects number of leaves, leaf size, seed size, test weight and overall biological and economic yields of sunflower crop.

2.4.1. Urea fertilizer

Urea is a nitrogen fertilizer which belongs to amides chemical family. Its molecular formula is CH_4N_2O and can be presented as $CO (NH_2)_2$. Its active ingredient is nitrogen 46% (Tisdale *et al*., 2002). It is a solid white granules nitrogenous fertilizer which was first introduced in the market in 1935. Nitrogen in it becomes available for plants uptake when it is converted to ammonium (NH_4^+) and nitrate (NO_3^-). It is a widely used nitrogen fertilizer due to its high nitrogen content of 46% N, low price per unit nitrogen, rapid conversion to available nitrogen and easy handling. The fertilizer can be applied as top dressing, starter and broadcast in different field crops including sunflower. However, it has high potential to caking if not properly managed in store and easily volatilized in the specified field conditions; if applied too close to the plants and seed it can cause crop and seedling damage (Jones et al., 2007). Proper application in annual crops is in the inter-row space as this allows better access of fertilizer by the roots and avoids contact with seeds and seedlings.

2.4.2. Farmyard manure

Manure is organic matter used as sources of plant nutrients (organic fertilizer in agriculture). They contain plant nutrients in complex organic forms. Most animal manure is faeces.

It is composed of cow dung, urine, waste straws and other dairy wastes. Farmyard manure is mostly available and produced from livestock keeping farms and is an important organic source of plant nutrients in livestock based farming systems in Morogoro region where there are Maasai livestock keepers. Farmyard manure is rich in nutrients, small portion of its nitrogen is readily available for plants uptake and large portion is released as it decomposes and after decomposition. Manure supplies plant nutrients both macro and micronutrients and increase their availability for plants uptake; improves soil physical properties like structure and water holding capacity and create suitable environment for soil microorganisms activity as it has been reported by Gotrapel, (2000) in the study of effects of organic, inorganic and integrated fertilizers on quantitative traits of different cultivars of sunflower in Iran.

Though farmyard manure has low nutrient content per unit quantity, they have longer residual effect in the soil and comply with slow release form of fertilizers. They are referred to as bulky organic manures as opposed to concentrated organic manure like oilseed cakes, bones and animal blood which have high percentage of nutrients.

However, manure nutrient status depends much on quality of animal feeds, composting method, storage and application. Kimani *et al*., (1999) in the study of bean maize intercropping, phosphorus and manure addition on nitrogen fixation and grain yield of *Phasiola vulgaris* in Kenya also reported that well made, carefully conserved, evenly applied and immediately incorporated farmyard manure and slurry play significant role in improving soil fertility both in the year of application and subsequent years in Kenya.

2.5. Agronomy and growth requirements of sunflower

Sunflower requires 11 days from planting to emergence, 33 days from emergence to head visibility, 27 days from head visibility to first anther, 8 days from first anther to last anther and 30 days from last anther to maturity (DPP, 2010). This makes the total growing period for the crop to range from between 120 to 135 days. Sunflower leaves are phototrophic (follows the sun rays) this tendency has shown to increase sunlight interception which in the end increases the rate of photosynthesis.

2.5.1 Tillage, seed bed preparation and planting

Like other crops, sunflower requires proper seed bed for optimum plant establishment. Tillage is normally done in order to control weeds as well as to improve soil physical conditions like water holding capacity and soil aeration. It can be grown under zero tillage (no till) where there is very minimal disturbance of the soil and crop residues are maintained for the purpose of maintaining soil microbial population as well as reducing the surface area for soil water evaporation. In Tanzania conventional tillage is very common in sunflower field preparation. Most of the crop residues are buried or incorporated in the soil during seedbed preparation, weeding and incorporation of fertilizers and herbicides in the soil. After conventional tillage, the surface is left relatively bare with no cover protection (Berglund, 2012).

Early planting guarantees the high yields with good quality crop in Sudan (Yousif *et al*., 2013). In Tanzania, planting is conducted at the onset of long rains in different regions. Late planting might result in low yields with low oil content as a result of poor rainfalls in the end of the season. For example in the eastern part of the country planting should be done in mid march (onset of long rains), and in the central part of the country (Dodoma, Singida) high yield seed with high oil content are obtained from crops planted in late December to early January in Tanzania (Msanya *et al*., 1991). Suitable soil temperature for sunflower planting and high germination percentage ranges from 7.2^0C to 10^0C in 4 inch depth (Helmy, 2009).

2.5.2 Row spacing and plant population

Sunflower plants will compensate for differences in plant density by adjusting seed size and head size. Thus as plant population decreases the head and seed size will increase. This is suitable scenario in production of confectional sunflower seeds. For oilseed type plant population can be as high as 62,500 plants/ha because seed size is not important attribute for yields and quality (Berglund, 2007). The above plant population can be achieved by intra and inter row spacing of 20 cm by 70 cm respectively.

2.6 Soils and soil fertility

Sunflower is adapted to a wide range of soil conditions but grows best on well drained soils, with good water holding capacity mainly in drylands (DPP, 2010). Sunflower grows well in nearly neutral soils pH (6.5 to 7.5). Soils with 20% clay and above limit the plant root penetration. Major sunflower producing areas have less than 20% clay (Sandy loam). The plant also has low salt tolerance in South Africa (DPP, 2010).

Sunflower like other green plants require at least 16 elements for growth and reproduction (completion of life cycle). Carbon (C), hydrogen (H) and oxygen (O) from air and water as well as other nutrients obtained from the soil. Nitrogen (N), phosphorus (P) and sulphur (S) are limiting in soils of any climatic conditions; potassium, calcium and magnesium are frequently deficient in areas with high rainfall (above 1000 mm/year). Deficiency of plant micronutrients like iron, zinc, manganese and cobalt is not common in sunflower production but can appear in highly acidic soils like oxisols and ultisols in US (Berglund *et al*., 2007). Soil fertility is determined by soil testing to determine the availability and amount of essential nutrient elements in the soil. This procedure is important in determination of nutrient content of the soil and prediction of probability response of added fertilizers/ nutrients in the soil. Berglund et al., (2007) also reported that, a field classified as very low in a nutrient, will give yield response of 80 to 100 % towards the added nutrient in US. Field testing very high in a nutrient will show no yield response towards the added fertilizer/nutrient because there are adequate nutrients required for a plant growth and development.

2.6.1 Fertilizer recommendations

The main factors in fertilizer recommendations are soil analysis results and yield goal. A yield goal for sunflower should be positively thought than average yields in order to meet the economic returns from the field. Many sunflower growers believe that sunflower does not require additional nutrient sources like cereal crops because it is a deep rooted crop with extensive root system therefore it can access nutrients from deep soil horizons.

In contrary to this belief, Daffalla *et al*., (2006) reported that seed yield increase with the increase in the amount of nitrogen fertilizers added in Sudan. Similar results were reported by Helmy and Ramdan, (2009) in Egypt. This proves that land productivity can be improved through application of recommended rates of fertilizers for better yields not only for sunflower crop but also for many other agronomic crops.

2.6.2 Fertilizers application

Nitrogen fertilizers are applied in the soil basing on the target yield and soil type. DPP, (2010) reported that for target yield of 1000 kg/ha in the clay soils, there is no need of applying nitrogen fertilizers while in other soils 0-15 kg of nitrogen per hectare of nitrogen should be added in South Africa. For yield target of 1500 kg in clay soils, 0 to 15 kg/ha of nitrogen should be applied and 25 to 35 kg N/ha of nitrogen in other soils. In order to obtain yields of 2000 kg/ha in clay soils, nitrogen recommendation is 40 to 50 kg N/ha while in other soils 60 to 70 kg N/ha is recommended. Warick, (2001) also reported that, 60 kg N/ha should be applied in a yield goal of 1200 kg/ha in San Angelo. Similar findings were also reported by Hussain *et al*., (2010) that application of organic and inorganic fertilizers increases plant height and dry matter yield in India.

The optimum phosphorus level for sunflower production is 10 mg/kg of soil. In this regard, phosphorus fertilization is necessary only when phosphorus level in the soil is below 10 mg/kg of soil (DPP, 2010). Similar findings were also reported by Rasool *et al*., (2013).

2.6.3 Organic sources of nutrients

Current agricultural production focuses on reduced costs of production and conserving the natural resource base (Munir et al., 2007). Use of organic sources of nutrients in the soil increases soil productivity by improving plant nutrient availability and soil physical and chemical properties. There is thus an increasing trend in the use of farmyard manure, green manure (Compost) and poultry manure because of high prices of industrial fertilizers and awareness towards sustainable agricultural production (eco efficiency production).

Farmyard manure in sunflower production has been reported to increase both sunflower oil quality and yield attributes, where poultry manure has shown the best response when compared with all other sources of manure in India (Rasool *et al*., 2013).

2.6.4 Inorganic sources of nutrients

Plant nutrients are obtained from inorganic fertilizers with different formulations based on the nutrient elements they contain. Common fertilizers used in sunflower and other crops include nitrogenous, phosphate and potash fertilizers. Sulphur also has been known to play important role in sunflower production. Sulphur helps in synthesis of Cystine, methionine, chlorophyll, vitamins (B, thiamine) and carbohydrate metabolism in soy bean crop in India (Najar *et al*., 2011). Filho *et al*., (2011) on the other hand reported that increase in nitrogen rates increased sunflower growth traits which are stem, leaves, head and fresh and dry weights in Brazil.

Rasool *et al*., (2013) reported that nitrogen is the most limiting nutrient in sunflower growth and development in India. It helps the plant in early vegetative growth, better assimilation of carbohydrates and protein synthesis and high biomass formation. In the report of Rasool *et al*., (2013) also indicated that nitrogen affects seed quality by increasing proteins and reducing oil concentration. Munir *et al*., (2013) also found that addition of inorganic nitrogen improved nutrients availability and uptake which led to increased achene and biological yields as a result of increased leaf area index, crop growth rate, net assimilation rate as well as biomass formation in Afghanistan. Similar findings were reported by Gotrappel *et al*., (2000) that in Iran inorganic fertilizers alone or in combination with manure showed higher achene and biological yields than the control. This indicates that addition of nitrogen fertilizers and farmyard manure is important in ensuring high yields of sunflower seed and the oil content.

2.7 Lodging as a factor affects sunflower production

Lodging is the detachment of the plant from the soil. (Pinthus, 1973). It occurs as a result of interaction between wind, rain and soil with the plant. Wind force exerts leverage on the plant, rain water on foliage and the head increases the bending force of the stems and shoots and also decreases soil strength and anchorage. There are two types of crop lodging. These are root lodging and stem lodging HGCA (2005).

Root lodging occurs where the plant roots detach from the soil due to root insufficient strength to hold the plant up against the wind force. This strength depends on spread and depth of the root plate and strength of the surrounding soil. Stem lodging occurs as a result of the plant stems buckle or fold. This occurs as a result of insufficient stem base strength to hold the shoot up against leverage. The strength depends on the stem diameter, composition and the width of the stem walls HGCA (2005).

Despite the yield advantage of sunflower high populations the risk of lodging increases as plant population in the field increase (Robinson, G.R 2009). The risk sometimes is so serious to the extent of discouraging the use of high populations.

2.7.1 Effects of Lodging in Sunflower

Severe lodging affects grain formation and associated harvesting problems and losses. It takes about twice the time to harvest a lodged crop than a standing one. Secondary growth in combination with a flattened crop makes harvesting difficult and can subsequently lead to poor grain quality and high yield losses. Sterling and Baker (1998), and Berry *et al.* (2000).

Lodging alters plant growth and development. It affects flowering, reduces photosynthetic capabilities of the plant, hence affecting carbohydrate assimilation. Severe lodging interferes with the transport of nutrients and moisture from the soil, and thus with food storage in the developing kernels. Lodging always results in some yield loss, and if permanent lodging occurs shortly after heading, the yield reduction can be as high as 40 per cent (Robinson, G.R 2009). Yield losses from lodging become smaller as the crop matures, but losses will continue until the kernels are completely filled. Incomplete filling results in small kernels, lowered carbohydrate content, and lower test weight (Robinson, G.R 2009). Lodging often contributes to uneven maturity, high moisture constant and loss of grain quality due to sprouting and possible moulding. Excessive moisture often delays harvest and may necessitate grain drying. And all these result in increased harvesting costs.

CHAPTER 3: MATERIAL AND METHODS

3.1 Description of the experimental site

The study was conducted in Morogoro- Tanzania, at Sokoine University of Agriculture, Department of soil science experimental sites. Sokoine University of Agriculture is located at longitude 6^0 $51^{'}$ 5 E latitude 39^0 $37^{'}$ 26 S, at the base of Uluguru mountains, 200 km west of Dar es Salaam on an altitude of 600 m above sea level. Morogoro region has a bimodal rainfall pattern characterised by short rains which start from mid September to December with total rainfall amount of 700 mm and 1000 mm for long rains which start from mid March to June every year. During this experimental period short rain season from October 2013 to February 2014, 200 mm of rain was recorded, and 500 mm was recorded during long rain season of March to July 2014. The difference in the start of seasons might have caused by the change of weather patterns which might have been associate by climate change. The first season was supplemented by irrigation because the rains were low and poorly distributed throughout the season. Mean monthly maximum and minimum temperatures were 31 ^{0}C and 20 ^{0}C respectively. The weather data during the experimental period for both seasons are shown in Appendix 1. The soils were red, friable sandy clay with pH range of 5.5 to 6.0 and soil extractable P of 0.024% (P_2O_5), total N 0.12 % and cation exchange capacity (C.E.C) of 17 Cmol/kg. Soil analysis results are shown in the results section.

First planting was done on 10/10/2013 and harvested on 10/02/2014 equivalent to 122 days from planting to harvesting. The second season trial was planted on 29th March 2014 and harvested on 17th July 2014, equivalent to 113 days from planting to harvesting.

3.2 Experimental designs, treatments and crop husbandry

3.2.1 Land preparation, field layout and planting

In the first season primary tillage was conducted before onset of short rains by using a tractor, followed by secondary tillage / harrowing before field layout by using a hand hoe and 7 m *5 m were used. Spacing used was 20 cm * 70 cm and these plots were maintained for use in the second season. The residual effect of the first treatment was determined by using the extrapolation of the plant nutrient uptake and removal from the plant tissue analysis data from the two seasons. The seed beds were prepared by using hand hoe and 30 cm ruler in making planting hills of 10 cm depth. From seed to seed the distance was 20 cm and from row to row the distance was 70 cm.

Farmyard manure (FYM) was applied at planting in 3 cm to 5 cm depth in a 10 cm planting hill and was covered by a thin layer of soil prior to placement of the seed. Two to three seeds were placed manually in each planting hill and were thinned to one seedling per hill in 12 days after germination as per farmers' practice.

Inorganic nitrogen fertilizer in form of urea was applied/ top dressed 30 days after seedlings emergence. Manure which was analysed for nutrient content was obtained from nearby Magadu farm, sunflower seeds (*Record*) were sourced from Agricultural Seed Agency (ASA) and Agro Seed International ltd and urea was obtained from agro dealer's shops in Morogoro town.

3.2.2 Irrigation and pests control

Supplemental irrigation in form of flooding was organized during short rains experiment where long dry spells could be experienced. A 50 m water pipe and irrigation machine was used to draw water from the nearby well and a stop watch was used to calculate the time taken to irrigate

60 litres of water per plot. The pressure of water flow was maintained in order to ensure uniform application of water throughout the plots.

Weeding was done thrice a season by using hand hoe to keep the plots free from weeds. First weeding was done when the seedlings were 5 cm high with 3-4 true leaves and during vegetative growth stage 6 when plants had 12 to 14 true leaves. The last weeding was done during flowering at reproductive stage II (R 2).

Murcloprid a.i (active ingredient) imidacloprid 250 g/kg)) insecticide which is effective in controlling aphids, whiteflies, thrips and leafminers in sunflower was applied at a concentration of 20 g per 40 litres in the entire experimental area. ATTAKAN C. (344 SE, a.i Imidacloprid 200 g/L and cypermethrin 144 g/L) is a systemic insecticide with contact and stomach action efficient in controlling of bollworms and sucking pests. Forty mls of an insecticide were added in a 20 litres knapsack sprayer, and the mixture was sprayed in the entire experimental area. Spraying was repeated three times after every 5 days. SUPATRHIN 5EC. (5 Emulsifiable Concentrate, a.i lambda cyhalothrin EC 50 g/L), non systemic broad-spectrum insecticide with contact and stomach action for control of sucking and biting insect pests in onions and other vegetables as well as field crops were applied to control aphids and white flies in sunflower experimental field. Birds were scared using reflecting tapes placed to surround the plots and shaking of stones placed in the small tin bottles on day time hours were the prevalent method used to ensure that the crop was free from birds' depredation and damage.

3.3 Soil sampling and analysis

Soils of the experimental site and manure were sampled and prepared for physico-chemical check one week before first planting. The soil sample was collected from the top soil 30 cm depth at 15 points by using a hand hoe within a furrow slice. A 0.25 kg sample from each block was air dried for two weeks, ground, sieved in a 2 mm sieve and were analysed at the soil science department of Sokoine University of Agriculture. Analyzed plant nutrients include: pH, organic carbon by wet titration method, electric conductivity (E.C) nitrogen by Kjedahl method, macro nutrients (Nitrogen, Phosphorus, Potassium and Sulfur) Exchangiable bases (Mg, Ca, K) micronutrients (Fe, Zn, Mn, Cu, Bo) Cation Exchange Capacity (C.E.C) by atomic absorption method. The soil physical properties determined were particle size analysis and texture. The soil analysis data are shown in the results section.

3.3.1 Soil pH

Soil pH was determined in 1: 2.5 soil: water and soil: 0.01M $CaCl_2$ ratio suspensions by the potential metric method (Mclean, 1986). To 10g of soil samples 25ml of distilled water were added and shaken on reciprocating mechanical shaker for 30 minutes. The pH of soil sample was determined using a pH meter.

3.3.2 Electric conductivity (E.C)

Electric conductivity was determined in a 1:1 soil: extract suspension as described by (Slavich and Petterson 1993). To 40 g of soil samples 40 ml of distilled water were added and shaken on a mechanical shaker for one hour. The suspension was centrifuged at 5000-6000 r.p.m for 10 minutes, the clear solution was decanted into another 100 ml plastic beaker and the E.C of soil sample was determined by using a dry electrode.

3.3.3 Particle size analysis

Particle size analysis was determined by the bouyoucos hydrometer method after soil dispersion in sodium hexametaphosphate as described by Day (1965) and NSS (1990). Then textural class was determined using the USDA textural class triangle.

3.3.4 Organic Carbon

Organic carbon was determined by using the Walkey-Black method (Nelson and Sommers, 1982). To a 0.5 g of soil sample 10 ml of 1 ml K_2 Cr_2 O_7 and 20 ml of concentrated H_2SO_4 were added and allowed to stand for 30 minutes to oxidize the soils organic. 200 ml of water were added to cool the mixture followed by addition of 10 ml of phosphoric acid (85% H_3 PO_4) to sharpen the end point. The amount of dichromate reduced was used to estimate the organic carbon of the soil following titrating of the excess dichromate against a ferrous sulphate solution using diphenylamine indicator.

3.3.5 Total nitrogen

Total nitrogen was determined by the micro kjedahl digestion- distillation method according to the procedure described by Bremner and Mulvaney (1982). 1 g of soil sample was digested with concentrated H_2S0_4 in presence of catalyst (K_2SO_4 + $CUSO_4$ + Selenium powder mixed in the ratio of 10: 10: 1 by weight). The digest was distilled in the presence of 40% NaOH. The NH_3 liberated was collected in 4% boric acid (mixed with indicator) and titrated against standard 0.05M H_2SO_4. The titre was used to calculate the total nitrogen content of the soil sample.

3.3.6 Extractable phosphorus

Extractable P of the soil sample was determined using the Bray 1and Kurtz (1945) because the all the samples had pH < 7. In the bray 1 method, the extracting solution containing 0.03M NH_4F and 0.025M HCL was used. A sample of 3.5 g of air dried soil was placed in a plastic bottle and 20 ml of extracting solution was added shaken by hand for 1 minute and filtered using Whatman No. 2 filter paper into a dry plastic vial. 2 – 5 ml of filtrate aliquots were used for colour development in a 50 ml volumetric flask using a molybdenum blue method (Murphy and Riley, 1962). The extractable P was determined by a spectrophotometer at the wavelength of 884 nm.

3.3.7 Sulphur

Sulphur was determined by turbimetric method by means of colour spectrophotometer (Petersen, 1996). To a 5 g of soil sample, 25 ml of sulphur extracting solution were added. The suspension was shaken for 30 minutes and filtered into a dry 100 ml flask. 10 ml of the soil extract were pipetted into a 100 ml beaker. 10 ml acid seed solution and 5 ml turbimetric reagent were added by means of dispenser and mixed. The mixture was frequently shaken for next 20 minutes and then, the absorbency was measured on a spectrophotometer at 535 nm.

3.3.8 Cation exchange capacity (CEC) and exchangeable bases

The CEC of the soil was determined by the ammonium acetate (NH_4OAC) saturation method as described by Chapman (1965). 5 g of the soil sample was saturated with a neutral normal NH_4OAC, shaken for 30 minutes and filtered. The filtrate used to determine exchangeable bases using atomic absorption spectrophotometer. Excess NH_4OAC in the sample were removed by washing twice using methanol. The NH_4^+ saturated soil was equilibrated with 4% KCl, shaken for 30 minutes and filtered. The filtrate was used for determination of NH_4^+ by micro kjedahl distillation in the presence of 40 % NaOH and NH_3 libarated was collected in 4% boric acid with mixed indicators and titrated with standard 0.1M H_2SO_4. The titre was used for the estimation of CEC.

3.3.9 Micronutrients

DTPA extractable micronutrients in all soil samples were determined using the procedure by Lindsay and Norwell (1978). The extractant contained 0.005M DTPA (Diethylenetriamine Pentaacetic acid), 0.01M CaCl . $2H_2O$ and 0.1M TEA (Triethanolamine) adjusted to pH 7.3. 20 g of soil sample were placed into a 100 ml plastic bottle and mixed with 40 ml of the extracting solution. The contents were shaken using a mechanical shaker for exactly two hours and filtered using Whatman No. 2 filter paper into a dry plastic vials. The micro nutrients Zn, Cu and Fe were determined by atomic absorption spectrophotometer (AAS) using appropriate wavelength of hollow cathode lamps specific to specific elements with standard of known concentration. Using appropriate standard curves of the known concentrations of the elements, the concentration of elements in the unknown concentrations were estimated.

3.4 Research design and treatments

The design of an experiment was Randomized Complete Block Design laid out on an area of 1135 m^2, with three blocks each block having ten 35 m^2 plots arranged in a 5 by 5 lines. The land terrain being the blocking factor, and blocks were arranged following the slope. Where block I was upper followed by block II and block III was located down the slope. The field layout of the experiment is shown in the appendix section.

(i) Control (no nitrogen fertiliser, no farmyard manure

(ii) 2 t farmyard manure (0.01 kg N) (FYM)/ha applied at planting

(iii) 5 t FYM/ha(0.03 kg N) applied at planting

(iv) 10 t FYM/ha(0.51 kg N) at planting

(v) 20 kg N/ha applied as urea at 30 days after planting

(vi) 40 kg N/ha applied as urea at 30 days after planting

(vii) 60 kg N/ha applied as urea at 30 days after planting

(viii) 2 t FYM/ha (0.01kg N) at planting + 20 kg N/ha applied as urea at 30 days after planting

(ix) 5 t FYM/ha (0.03 kg N) at planting + 40 kg N/ha applied as urea at 30 days after planting

(x) 10 t FYM/ha (0.05 kg N) applied at planting + 60 kg N/ha applied as urea at 30 days after planting

The treatments were laid down in a randomized complete block design and replicated three times. Each 5 m by 7 m experimental plot consisted of six planting rows each row having 34 planting hills making a plant population of 204 per plot. Two to three sunflower seeds were planted per hill and later were thinned to one plant per hill. Short rains continued and supplemental irrigation was carried out whenever long dry spell resulted.

3.5 Plant tissue analysis

Plant tissue analysis was conducted to determine the soil nutrient status during the two crop growth seasons. At 60 days after planting five plants were sampled randomly from which three newly matured or new fully developed leaves were sampled. Sampled leaves from each plot were placed in a paper bag and transferred to the glass house for under shade drying. The leaves were left to air dry for two weeks, and then were oven dried at 70 ^{0}C for two days prior to grinding. Oven dried leaves were ground using a Wiley Mill grinding machine to a fine powder. The ground samples were weighed and digested for determination of nutrients concentrations, both macro and micronutrients content by the wet ashing procedure. The procedure consisted of digesting 0.5 g of plant sample using H_2O_2 – $HClO_4HF$, heated in tubes in a block digester at 200 ^{0}C for 2 hours. The digest were cooled and made up to volume (50 ml). The nutrients content of the plants extracts were determined as for soils (section 3.3)

3.6 Data collection and analysis

3.6.1 Sunflower plant growth parameters

The variables measured included: number of leaves per plant at 15, 30 45, 60 and 75 days after planting, plant height at 15, 30,45, 60 and 75 days after planting and head diameter at sunflower plant physiological maturity.

Number of leaves and plant height were determined by sampling 5 plants falling within the four middle rows. Plant height was measured using a 1 m ruler, while all leaves (including young newly formed leaves) were counted manually.

Data on the number of leaves and plant height was collected at 15 days interval until 75 days after emergence.

Five sunflower plants were sampled in the four middle rows in a plot at reproductive stage 8 (R8) and the head diameter was measured. At this stage the plants were fully matured, the petals had dried and the bracts had turned brown. The diameter in cm was measured using a 30 cm ruler.

Data collected from each variable was subjected to analysis of variance using Gen Stat discovery edition 13 statistical package at 5% probability level. Treatment means were compared using the least significant difference (LSD) test at 5% probability level.

3.6.2 Sunflower total biomass, seed yield and yield components

Data on total biomass was collected during harvesting, while seed yield and 1000 seed weight data were collected after harvesting. Sampling was carried out in three centre rows in each plot occupying area of 8 m^2. Sunflower heads were removed using a hand knife and were kept in the 30 kg manila bags during harvesting. Few seeds from the heads were removed and seed moisture content during harvesting was determined using a grain moisture meter. The harvested heads were air dried at the glass house for two weeks and then was processed to obtain sunflower seeds. The seeds obtained from each plot were weighed using a weighing balance and seed yield per plot was obtained in g/8 m^2.

30 sub samples of 100 g sunflower seeds from the seed yield were set aside and were taken to a seed counter machine. A count A Pak seed counter machine was used to count a thousand seeds from each sample. The 1000 seed counted from each sample were weighed in a weighing balance and weight of 1000 sunflower seed (g) was obtained.

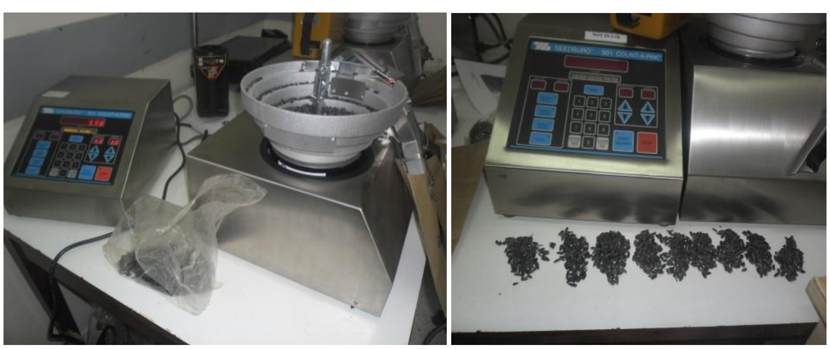

Figure 2: Sunflower 1000 seed weight determination

Five sunflower plants were sampled in the four middle rows in a plot and the plant shoots were cut above the ground using a sharp knife. The shoots from each plot together with the leaves and heads were cut into pieces and air dried in the glass house for two weeks. The shoots (together with the leaves and heads) were sliced, packed in the well labelled A3 envelopes and were oven dried at 70 ^{0}C for 72 hours. The oven dried matter was weighed and the biomass yield obtained. After weighing the seeds from each biomass sample were taken back to the respective seed yield samples.

Data collected from each variable was subjected to analysis of variance using Gen Stat discovery edition 13 statistical package at 5% probability level. Treatment means were compared by using least significant difference (LSD) test at 5% probability level.

3.6.3 Sunflower seed oil content and total seed oil yield

For oil determination and quantification, 30 samples of 20 g dehulled seeds from each plot were taken to food science laboratory for oil extraction by using soxhlet extraction method by Franz von Soxhlet, (1879). The seeds were ground to obtain the fine powder and 5 g of ground seeds from each sample was weighed and placed in a thimble. The thimbles was covered with a cotton wool to avoid loss of the sample during oil extraction in the soxhlet apparatus and were placed in the pre weighed round bottomed flasks containing 250 ml of petroleum ether as an extraction solvent and then were arranged in the soxhlet extraction apparatus. After 3 hours the flasks were removed from soxhlet apparatus and were left to cool. After cooling the flasks with crude fat plus solvents were taken to evaporator and were dipped in the 70 ^{0}C boiling water until no more moving solvents could be seen. The flask with crude fat was taken to the oven at 105 ^{0}C for 30 minutes to allow more evaporation of organic solvents. The flask with oil was placed in the desiccators for 45 minutes to attain the ambient temperature, and then was weighed to obtain the weight of flask + oil. Method of analysis used was as described by Leas, (1975) and fat/oil extraction manual from the department of food science and technology of the Sokoine University of Agriculture.

Figure 3: Sunflower oil determination

To obtain a percentage oil the following calculation was carried out.

% Oil/fat Content = ((Weight of flask + oil- Weight of empty flask)/ weight of Sample) * 100.

Percentage oil data obtained from each sample was subjected to analysis of variance using Gen Stat discovery edition 13 statistical package at 5% probability level. Treatment means were compared by using Least Significant Difference (LSD) test at 5% probability level.

CHAPTER 4: RESULTS

4.1. Soil physical and chemical analysis

Determination of soil fertility of the experimental blocks prior to planting during the short rain season of 2013/204 and the composition of farmyard manure. The results show that the soils were sandy clay, slightly acidic non saline with medium, sufficient and high levels of most of the nutrients except for Nitrogen and Calcium which were low and Zinc which was very low (Table 1).

Table 1: Soil fertility status of an experimental site before planting

Properties	Block 1	Block 2	Block 3
	Value	Value	Value
A: Physical properties			
Sand (%)	48	48	48
Silt (%)	9	11	9
Clay (%)	42	40	44
Textural Class	Sandy clay	Sandy clay	Sandy clay
B: Chemical composition			
pH	5.65M	5.7M	5.7M
Electric conductivity (mS/cm)	0.07 NS	0.07 NS	0.07 NS
Organic carbon (%)	1.58M	1.58M	1.66M
Total N (%)	0.12L	0.12L	0.12L
Total P bray1(mg/kg)	676.07	1038.88	2688.04
Extractable P (mg/kg)	10.03M	9.22M	10.16M
Cation exchange capacity (cmol/kg)	18.03M	17.8M	17.8M
K+ (cmol/kg)	0.76H	0.98H	0.89H
S (mg/kg)	52.52VH	52.52VH	31.2H
Cu (mg/kg)	1.79 H	1.58 H	1.53 H
Mn (mg/kg)	112.2VH	121.6 VH	124.74 VH
Zn (mg/kg)	0.97VL	0.97VL	0.88VL
Fe (mg/kg)	49.8VH	47.13VH	44.44VH
Ca2+ (cmol/kg)	4.88L	3.9L	4.9L
Mg2+ (cmol/kg)	2.79M	2.69M	2.64M
K+ (cmol/kg)	0.76H	0.98H	0.89H
Na+ (cmol/kg)	0.2L	0.71H	0.39L

C: composition of farmyard manure

Total N (%)	0.512 H
P_2O_5 (%)	1.94M
K_{2O} (%)	1.16M

The rating of soil analysis data L = Low, M = Medium, H = High, VH = Very High and NS = Non Saline were according to Jones, (2001)

4.2 Sunflower plant tissue analysis for short rain season and long rain season 2013/2014

The amount of macronutrients determined during the short rain season ranged from medium to sufficient (Table 2a). The plant materials had low levels of calcium. During the long rain season the plant material had very high levels of nitrogen, high levels of potassium and sulphur and low to medium levels of phosphorus (Table 2b),

Table 2a: Plant tissue analysis results for short rain season 2013/2014

Treatments	N (%)	P (%)	K (%)	S %	Ca (%)	Mg %)
Control (No fertilizer)	2.60 S	0.32 S	1.15 M	0.24 S	0.12 L	0.16 M
20 kg N/ha	2.94 S	0.37 S	1.19 M	0.24 S	0.06 L	0.14 M
40 kg N/ha	3.18 S	0.34 S	1.30 M	0.21 S	0.10 L	0.16 M
60 kg N/ha	3.23 S	0.37 S	1.24 M	0.23 S	0.18 L	0.17 M
2 t FYM/ha	3.07 S	0.39 S	1.44 M	0.24 S	0.14 L	0.16 M
5 t FYM/ha	3.06 S	0.40 S	1.17 M	0.22 S	0.15 L	0.15 M
10 t FYM/ha	2.86 S	0.40 S	1.47 M	0.24 S	0.16 L	0.15 M
20 kg N/ha +2 t FYM/ha	3.18 S	0.37 S	1.59 S	0.23 S	0.15 L	0.14 M
40 kg N/ha +5 t FYM/ha	3.17 S	0.39 S	1.3 M	0.23 S	0.15 L	0.19 M
60 kg N/ha +10 t FYM/ha	3.26 S	0.30 S	1.28 M	0.21 S	0.16 L	0.18 M

N.B: the rating of plant tissue data; L = Low, M = Marginal, S = Sufficient, H = High and E = Excess were according flower plant tissue interpretation (http://www.sdstate.edu/ps/extension/soilfert/index.cfm)

Table 2b: plant tissue analysis data for long rain season 2014

Treatments	N (%)	P (%)	K(%)	S (%)
Control (No fertilizer)	4.43 E	0.13 L	3.79 H	0.67 H
20 kg N/ha	4.41 E	0.11 L	4.91H	0.33 H
40 kg N/ha	4.47 E	0.14 L	3.80 H	0.41 H
60 kg N/ha	4.75 E	0.13 L	5.08 E	0.45 H
2 t FYM/ha (residual)	3.81 E	0.15 M	3.99 H	0.45 H
5 t FYM/ha(residual)	3.19 E	0.20 M	4.49 H	0.44 H
10 t FYM/ha(residual)	3.60 E	0.14 L	3.71 H	0.51 H
20 kg N/ha +2 t FYM/ha(residual)	4.61 E	0.13 L	4.33 H	0.44 H
40 kg N/ha +5 t FYM/ha (residual)	5.56 E	0.15 M	3.90 H	0.42 H
60 kg N/ha +10 t FYM/ha (residual)	4.61 E	0.18 M	5.15 E	0.47 H

N.B: the rating of plant tissue data; L = Low, M = Marginal, S = Sufficient, H = High and E = Excess were according flower plant tissue interpretation (http://www.sdstate.edu/ps/extension/soilfert/index.cfm)

4.3 Effect of FYM and Urea fertilizers application on growth of sunflower

4.3.1 Plant height

In the short rains fertilizer application had a significant effect ($P \leq 0.05$) on plant height at all sampling periods except at 15 days after planting (Table 3a). In most cases, plots supplied with farmyard manure alone or in combination with inorganic N- fertilizers had significantly taller sunflower plants than the no fertilizer control plots. Application of inorganic fertilizer alone did not increase plant height at all sampling times except at 75 days after planting where plants supplied with 40 kg N/ha were 30.5 % taller than the plants in the no fertilizer control plots. Plant height varied from 14.27 to 16.67, 39.73, to 53.53, 86.53 to 118.40, 138.2 to 189.1 and 142.5 to 194.7 cm at 15, 30, 45, 60 and 75 days after planting, respectively.

Table 3a: Effect of fertilizer application on sunflower plant height (cm) during the short rain season 2013/2014

Fertilizer regime	Days after planting				
	15	30	45	60	75
Control (No fertilizer)	15.83a	41.43b	86.53 c	138.20b	142.50b
20 kg N/ha	14.43a	45.83b	101.27bc	154.80b	144.90b
40 kg N/ha	14.93a	47.10ab	105.07b	172.50ab	185.90a
60 kg N/ha	14.27a	39.73 b	92.27c	150.90b	153.30b
2 t FYM/ha	16.67a	51.17ab	118.40a	165.30ab	194.00a
5 t FYM/ha	16.27a	41.07b	90.00 c	149.80b	157.10b
10 t FYM/ha	14.97a	53.53 a	105.87b	189.10a	189.30a
20 kg N/ha +2 t FYM/ha	14.57a	52.47a	111.73ab	158.60b	194.70a
40 kg N/ha +5 t FYM/ha	15.60a	49.67ab	97.20bc	166.70ab	161.70b
60 kg N/ha +10 t FYM/ha	15.60a	53.47 a	111.87ab	177.90ab	192.30a

P *value*	0.832	0.039	<.001	0.052	0.016
LSD *0.05*	n.s	6.10	10.63	24.55	23.83
C.V *(%)*	16.1	13.4	10.9	15.9	14.6

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test

In the long rains fertilizers application had a significant effect (P≤ 0.05) on plant height at all sampling periods except at 60 days after planting (Table 3b) combined application of 60 kg N/ha and 10 t/h FYM produced taller plants than all the fertilizer treatments at 15, 30 and 45 days after planting. For example plants supplied with a combination of 60 kg N/ha and 10 t/ha FYM were 72.5, 70.6 and 37.5 % taller than non fertilized plants at 15, 30 and 45 days, respectively. Generally application of 10 t FYM/ha, 5 t FYM/ha, 5 t FYM/ha + 40 kg N/ha and 10 t FYM/ha + 60 kg N/ha produced significantly taller plants than application of 20, 40 and 60 kg N/ha. Application of 20 kg N/ha had no effect on plant height relative to the no fertilizer control. At 75 days after planting sunflower plant height ranged from 270.6 to 310.7 cm. The average plant was 16.66, 23.30, 39.65, 67.58, and 69.43 % higher in the long rains than in the short rains at 15, 30, 45, 60 and 75 days after planting respectively.

Table 3b: Effect of fertilizer application on sunflower plant height (cm) in the long rain season 2014

fertilize regime	Days after planting				
	15	30	45	60	75
Control (No fertilizer)	13.33e	44.13d	123.40d	223.30a	281.90bc
20 kg N/ha	15.27d	44.87d	127.50d	219.10a	270.60c
40 kg N/ha	15.80d	49.33d	130.20cd	226.50a	284.60bc
60 kg N/ha	17.13c	57.47c	136.30cd	396.90a	294.90b
2 t FYM/ha(residual)	18.53c	56.87c	137.60c	233.30a	298.50ab
5 t FYM/ha(residual)	20.93b	67.60b	156.00b	252.20a	284.70bc
10 t FYM/ha(residual)	20.53b	66.93b	157.10b	261.20a	310.70a
20 kg N/ha +2 t FYM/ha(residual)	16.00d	56.67c	137.70c	399.10a	275.50c
40 kg N/ha +5 t FYM/ha(residual)	18.13c	67.13b	149.20b	254.80a	306.30ab
60 kg N/ha +10 t	23.0a	75.27a	169.70a	254.70a	299.20ab

FYM/ha(residual)					
P *value*	<0.001	<0.001	<.001	0.544	0.048
LSD *0.05*	1.69	6.86	9.27	n.s	15.62
C.V *(%)*	10.1	12.5	6.8	41.5	5.5

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s = not significant

4.3.2 Number of leaves

During short rains, fertilizer application had a significant effect (P≤ 0.05) on the number of leaves per plant at 45 and 75 days after planting but had no effect on this attribute at 15, 30 and 60 days after planting (Table 4a). At 45 days after planting all the fertilizer treated plots had significantly higher number of leaves per plant than the no fertilizer (control) plots. The number of leaves per plant ranged from 26.67 (control) to 31.87 (60 kg N/ha). At 75 days after planting application of 10 t FYM/ha had the highest number of leaves compared to all other treatments. The average number of leaves per plant ranged from 33.33 (control) to 39.67 (10 t FYM/ha).

Table 4a: Effect of fertilizer application on number of sunflower leaves per plant in the short rain season 2013/2014

Fertilize regime	Days after planting				
	15	30	45	60	75
Control (No fertilizer)	11.93a	24.00a	26.67c	31.20a	33.33c
20 kg N/ha	12.13a	24.47a	31.81ab	30.27a	35.13bc
40 kg N/ha	11.67a	25.60a	30.33b	29.67a	36.87b
60 kg N/ha	11.40a	23.93a	31.87ab	32.33a	35.53bc
2 t FYM/ha	13.67a	24.87a	31.53ab	31.40a	36.00bc
5 t FYM/ha	12.07a	24.40a	29.63b	31.07a	35.80bc
10 t FYM/ha	11.93a	26.47a	31.73ab	33.33a	39.67a
20 kg N/ha +2 t FYM/ha	11.53a	26.40a	31.73ab	27.07a	36.60b
40 kg N/ha +5 t FYM/ha	12.27a	24.80a	28.93b	32.00a	34.20c
60 kg N/ha +10 t FYM/ha	12.20a	25.67a	31.13ab	29.33a	35.13bc
P *value*	0.628	0.522	<0.01	0.416	0.018
LSD *0.05*	n.s	n.s	2.07	n.s	2.12
C.V *(%)*	8.5	8.4	7.1	8.8	6.1

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s: not significant

During the long rains the number of leaves per plant was affected significantly by fertilizer application (P≤ 0.05) at 15, 30 and 75 days after planting (Table 4b). A combination of 60 kg N/ha and 10 t FYM/ha had significantly higher number of leaves per plant than most of the other treatments across the three sampling periods. Plants supplied with 60 kg N/ha had significantly higher number of leaves than plants supplied with 20 and 40 kg N/ha at 30 and 75 days after planting. In contrast there were no significant differences among 2, 5 and 10 t FYM/ha treatments in the number of leaves per plant. The average number of leaves per plant ranged from 10.8 to 13.67, 18.80 to 24.77 and 30.80 to 38.20 at 15, 30 and 75 days after planting respectively. The short rain season had 1.12, 14.48 and 4.98 % higher average number of leaves per plant than the long rains at 15, 30 and 75 days after planting respectively. The long rain season had 3.88 and 4.62 % higher average number of leaves per plant than short rains at 45 and 60 days after planting respectively.

Table 4b: Effect of fertilizer application on number of sunflower leaves per plant in the long rain season 2014

Fertilizer regime	Days after planting				
	15	30	45	60	75
Control (No fertilizer)	11.87bc	18.80c	26.67a	30.87a	32.87bc
20 kg N/ha	11.13c	20.27c	29.73a	30.93a	30.80c
40 kg N/ha	11.67bc	19.60c	28.60a	30.87a	32.20c
60 kg N/ha	11.73bc	22.33b	30.13a	31.60a	35.53ab
2 t FYM/ha(residual)	11.40bc	21.87bc	28.93a	31.80a	35.40ab
5 t FYM/ha(residual)	12.93ab	24.13ab	31.07a	32.93a	33.35b
10 t FYM/ha(residual)	12.33b	21.33bc	51.47a	33.27a	36.07ab
20 kg N/ha +2 t FYM/ha(residual)	10.80c	20.87bc	30.40a	31.40a	31.73c
40 kg N/ha +5 t FYM/ha(residual)	11.93bc	23.53ab	29.27a	33.80a	35.13b
60 kg N/ha +10 t FYM/ha(residual)	13.67a	24.27a	30.93a	34.40a	38.20a
P *value*	0.006	<.001	0.189	0.112	0.024
LSD *0.05*	1.09	1.85	n.s	n.s	2.85

C.V *(%)*	9.6	8.9	33.9	5.9	8.5

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s = not significant

4.3.3 Head diameter

During both seasons fertilizer application did not significantly (P > 0.05) affect head diameter of sunflower plants (Table 5a and 5b). The average head diameter ranged from 14.00 (control) to 23.47 cm (5 t FYM/ha) in the short rains (Table 5). and 9.74 (20 kg N/ha) to 12.54 cm (60 kg N/ha + 10 t FYM/ha) in the long rains (Table 5). The short rains had 50.82 % higher average head diameter than the long rains.

Table 5a: Effect of fertilizer application on sunflower plant head diameter (cm) during the short rain season 2013/2014.

Fertilizer regime	Head diameter
	Short rain season
Control (No fertilizer)	14.00a
20 kg N/ha	15.83a
40 kg N/ha	16.53a
60 kg N/ha	16.00a
2 tones FYM/ha	15.20a
5 tones FYM/ha	23.47a
10 tones FYM/ha	18.50a
20 kg N/ha +2 t FYM/ha	16.47a
40 kg N/ha +5 t FYM/ha	16.60a
60 kg N/ha +10 t FYM/ha	18.83a
P *value*	0.235
LSD *0.05*	n.s
C.V *(%)*	31.4

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s = not significant

Table 5b: Effect of fertilizer application on sunflower plant head diameter (cm) during the long rain season 2013/2014.

Fertilizer regime	Head diameter (cm)
	Long rain season
Control (No fertilizer)	11.75a
20 kg N/ha	9.74a
40 kg N/ha	12.03a
60 kg N/ha	10.84a
2 tones FYM/ha (residual)	11.61a
5 tones FYM/ha(residual)	11.09a
10 tones FYM/ha(residual)	11.41a
20 kg N/ha +2 t FYM/ha(residual)	11.71a
40 kg N/ha +5 t FYM/ha(residual)	10.94a
60 kg N/ha +10 t FYM/ha(residual)	12.54a
P *value*	0.354
LSD *0.05*	n.s
C.V *(%)*	7.5

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s = not significant

4.4 Effect of inorganic nitrogen and organic fertilizers on sunflower yield and yield components

4.4.1 Biomass yield

In both seasons fertilizer application had a significant effect (P≤ 0.05) on sunflower shoot biomass (Table 6a and 6b). In the short rains 10 t FYM/ha gave higher biomass yield than all other treatments (Table 6a). Application of 10 t FYM/ha gave 107.9 % higher biomass yield than the no fertilizer control. There were significant differences in shoot biomass among the different inorganic nitrogen fertilizer rates and also among the farmyard manure rates. In the long rains a combination of 60 kg N/ha and 10 t FYM/ha had higher shoot biomass yield than all the inorganic fertilizer treatments (Table 6b), 2 t FYM/ha and 5 t FYM/ha. Application of 60 kg N/ha outperformed 20 kg N/ha by 21.4 %. The average shoot biomass ranged from 672.13 to

967.88 kg/ha. The short rains had 21.25 % higher average shoot biomass yield than the long rains.

Table 6a: Effect of fertilizer application on sunflower plant biomass (kg/ha) during the short rain season 2013/22013/2014.

Fertilizer regime	Biomass (kg)
	Short rain season
Control (No fertilizer)	638.25e
20 kg N/ha	977.25c
40 kg N/ha	1041.75bc
60 kg N/ha	1012.13bc
2 t FYM/ha	944.88c
5 t FYM/ha	800.13d
10 t FYM/ha	1326.75a
20 kg N/ha +2 t FYM/ha	1180.50b
40 kg N/ha +5 t FYM/ha	1061.75bc
60 kg N/ha +10 t FYM/ha	1095.25bc
P *value*	<.001
LSD *0.05*	144.30
C.V *(%)*	19.5

Table 6b: Effect of fertilizer application on sunflower plant biomass (kg/ha) during the long rain season 2013/2014.

Fertilizer regime	Biomass (kg)
	Long rain season
Control (No fertilizer)	672.13d
20 kg N/ha	676.13d
40 kg N/ha	784.88cd
60 kg N/ha	821.12c
2 t FYM/ha(residual)	842.75bc
5 t FYM/ha(residual)	853.13b
10 t FYM/ha(residual)	877.00ab
20 kg N/ha +2 t FYM/ha(residual)	676.13d
40 kg N/ha +5 t FYM/ha(residual)	784.88cd
60 kg N/ha +10 t FYM/ha(residual)	821.12c
P *value*	0.002
LSD *0.05*	111.50
C.V *(%)*	9.7

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test

4.4.2 Sunflower seed yield

During short rain season, fertilizer application rates had a significant effect ($P \leq 0.05$) on sunflower seed yield. In this season 10 t FYM/ha + 60 kg N/ha showed higher seed yield than the rest of the treatments (Table 7a). Seed yield obtained by application of 10 t FYM/ha was also higher than the control. Control plots showed lower seed yield than all the other treatments (Table 7a). Sunflower seed yield was 190.7 % higher in plots treated with 60 kg N/ha + 10 t FYM/ha than in the control plots. No seed yield differences were noted among 20, 40 and 60 kg N/ha and among 2, 5 and 10 t FYM/ha treatments. Fertilizer treatments in the sunflower seed yield were not significant in long rain season (Table 7b). Short rain season had 102.15 % higher average seed yield than the long rain season.

Table 7a: Effect of fertilizer application on sunflower seed yield (kg/ha) during the short rain season 2013/22014.

Fertilizer regime	Seed yield (kg/ha)
	Short rain season
Control (No fertilizer)	435.10c
20 kg N/ha	854.00b
40 kg N/ha	778.60b
60 kg N/ha	821.50b
2 t FYM/ha	1185.80a
5 t FYM/ha	987.60ab
10 t FYM/ha	992.80ab
20 kg N/ha +2 t FYM/ha	839.50b
40 kg N/ha +5 t FYM/ha	801.90b
60 kg N/ha +10 t FYM/ha	1265.00a
P *value*	0.001
LSD *0.05*	227.50
C.V *(%)*	35.5

Means bearing same letters along the column are not significantly different ($P < 0.05$) according to Duncan's New Multiple Range Test.

Table 7b: Effect of fertilizer application on sunflower seed yield (kg/ha) during the long rain season 2013/2014.

Fertilizer regime	Seed yield (kg/ha)
	Long rain season
Control (No fertilizer)	401.00a
20 kg N/ha	243.50a
40 kg N/ha	429.40a
60 kg N/ha	384.30a
2 t FYM/ha(residual)	528.50a
5 t FYM/ha(residual)	553.50a
10 t FYM/ha(residual)	421.90a
20 kg N/ha +2 t FYM/ha(residual)	518.00a
40 kg N/ha +5 t FYM/ha(residual)	327.40a
60 kg N/ha +10 t FYM/ha(residual)	567.80a
P *value*	0.1
LSD *0.05*	n.s
C.V *(%)*	29.5

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test.

4.4.3 1000 seed weight

In the short rains fertilizer application had a significant effect ($P \leq 0.05$) on sunflower seed weight (Table 8a). The plots supplied with 10 t FYM/ha + 60 kg N/ha had higher 1000 seed weight than plots from the other treatments. Control had a lower 1000 seed weight than the rest of the treatments (Table 8a). The 1000 seed weight ranged from 32.94 (control) to 51.61 g. Treatment effect on sunflower 1000 seed weight were not significant in the long rains (Table 8b). The average seed weight ranged from 27.42 to 33.62 g. Sunflower 1000 seed weight average was higher by 39.75 % in the short rains than in the long rains.

Table 8a: Effect of fertilizer application on sunflower 1000 seed weight (g) during the short rain season 2013/2014.

Fertilizer regime	1000 seed weight (g)
	Short rain season
Control (No fertilizer)	32.94d
20 kg N/ha	41.63c
40 kg N/ha	49.14ab
60 kg N/ha	45.23bc
2 t FYM/ha	44.25bc
5 t FYM/ha	42.12c
10 t FYM/ha	48.25ab
20 kg N/ha +2 t FYM/ha	49.89ab
40 kg N/ha +5 t FYM/ha	43.50bc
60 kg N/ha +10 t FYM/ha	51.61a
P *value*	<.001
LSD *0.05*	6.32
C.V *(%)*	15.1

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test.

Table 8b: Effect of fertilizer application on sunflower 1000 seed weight (g) during the long rain season 2013/2014.

Fertilizer regime	1000 seed weight (g)
	Long rain season
Control (No fertilizer)	33.62a
20 kg N/ha	27.42a
40 kg N/ha	32.46a
60 kg N/ha	29.11a
2 t FYM/ha(residual)	31.63a
5 t FYM/ha(residual)	33.11a
10 t FYM/ha(residual)	32.40a
20 kg N/ha +2 t FYM/ha(residual)	32.07a
40 kg N/ha +5 t FYM/ha(residual)	32.05a
60 kg N/ha +10 t FYM/ha(residual)	37.10a
P *value*	0.263
LSD *0.05*	n.s
C.V *(%)*	10.8

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test. *n.s = not significant*

4.5 Effect of inorganic nitrogen and organic fertilizer on sunflower seed oil content

4.5.1 Percent seed oil content

In both seasons fertilizer application had a significant effect ($P \leq 0.05$) on seed oil content (Table 9a and 9b). In the short rains, 10 t FYM/ha gave a higher percent of oil content than most of the other treatments (Table 9a). Percent oil content ranged from 33.67 to 47.35 %. In the long rain season, control had higher percent seed oil than most of the other treatments (Table 9b). Percent oil ranged from 23.71 (20 kg N/ha +2 t FYM/ha) to 44.56 % (control). Short rain had 23.82 % higher average percent seed oil than long rain season.

Table 9a: Effect of fertilizer application regime on sunflower seed oil content during the short rain season 2013/2014.

Fertilizer regime	Seed oil content (%)
	Short rain season
Control (No fertilizer)	40.05c
20 kg N/ha	44.24ab
40 kg N/ha	45.17ab
60 kg N/ha	39.32c
2 t FYM/ha	43.44b
5 t FYM/ha	33.67d
10 t FYM/ha	47.35a
20 kg N/ha +2 t FYM/ha	38.69c
40 kg N/ha +5 t FYM/ha	36.97c
60 kg N/ha +10 t FYM/ha	43.51b
P *value*	0.028
LSD *0.05*	3.23
C.V *(%)*	8.1

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test

Table 9b: Effect of fertilizer application regime on sunflower seed oil content during the long rain season 2013/2014.

Fertilizer regime	Seed oil content (%)
	Long rain season
Control (No fertilizer)	44.56a
20 kg N/ha	26.98cd
40 kg N/ha	36.63ab
60 kg N/ha	26.51c
2 t FYM/ha(residual)	40.99ab
5 t FYM/ha(residual)	27.58bc
10 t FYM/ha(residual)	33.71bc
20 kg N/ha +2 t FYM/ha(residual)	23.71d
40 kg N/ha +5 t FYM/ha(residual)	41.87ab
60 kg N/ha +10 t FYM/ha(residual)	30.52bc
P *value*	0.017
LSD *0.05*	9.64
C.V *(%)*	28.01

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test

4.5.2 Total seed oil yield

During short rains fertilizer application had a significant effect (P≤ 0.05) on total seed oil yield. During this season, 60 kg N/ha + 10 t FYM/ha had higher total seed oil content than most of the other treatments (Table 10a). Total seed oil yield ranged from 182.2 kg (control) to 552.1 kg (60 kg N/ha + 10 t FYM/ha). In the long rain season, treatment effect was not significant on total seed oil yield (P > 0.05) (Table 10b). The oil yield ranged from 64.9 (20 kg N/ha) to 223.7 kg (2 t FYM/ha). The short rain had 159.70 % higher total seed oil yield than the long rains.

Table 10a: Effect of fertilizer application on sunflower total seed oil content (kg /ha) in the short rain season 2013/2014.

fertilize regime	Total seed oil content (kg/ha)
	Short rain season
Control (No fertilizer)	182.2b
20 kg N/ha	364.5ab
40 kg N/ha	350.0b
60 kg N/ha	316.4b
2 t FYM/ha	519.7ab
5 t FYM/ha	319.9b
10 t FYM/ha	498.4ab
20 kg N/ha +2 t FYM/ha	333.2b
40 kg N/ha +5 t FYM/ha	311.9b
60 kg N/ha +10 t FYM/ha	552.1a
P *value*	0.018
L.s.d	189.20
C.V *(%)*	29.4

Means bearing same letters along the column are no significantly different (P < 0.05) according to Duncan's New Multiple Range Test

Table 10b: Effect of fertilizer application on sunflower total seed oil content (kg /ha) in the long rain season 2013/2014.

fertilize regime	Total seed oil content (kg/ha)
	Long rain season
Control (No fertilizer)	178.9a
20 kg N/ha	64.9a
40 kg N/ha	159.2a
60 kg N/ha	100.2a
2 t FYM/ha(residual)	223.7a
5 t FYM/ha(residual)	172.3a
10 t FYM/ha(residual)	126.1a
20 kg N/ha +2 t FYM/ha(residual)	113.5a
40 kg N/ha +5 t FYM/ha(residual)	137.6a
60 kg N/ha +10 t FYM/ha(residual)	166.9a
P *value*	0.114
L.s.d	n.s
C.V *(%)*	39.3

Means bearing same letters along the column are not significantly different (P < 0.05) according to Duncan's New Multiple Range Test. n.s = not significant

CHAPTER 5: DISCUSSION

5.1 Effect of nitrogen fertilizers, FYM and their combination on sunflower growth

The significant increase in plant height from both seasons could be attributed to the positive effect of nitrogen element in plant growth. Nitrogen application might have led to progressive increase in internodes length and consequently increase in plant height. Similar findings have been reported elsewhere (Al-Thabet, (2006): Hussain and Thomas (2010). Hussein and Thomas, (2010) in a study conducted in India reported that nitrogen application at 120 kg N/ha significantly increased plant height. Number of leaves per sunflower plant was significantly increased by nitrogen fertilization. This shows that sunflower number of leaves could significantly be increased by nitrogen levels higher than 60 kg N/ha. Al-Thabet, (2006) reported that, higher sunflower number of leaves per plant was recorded at 150 and 200 kg N/ha, and was attributed to an increase in vegetative growth as a result of availability of nitrogen.

The results also showed that application of 10 t FYM/ha gave taller plants from 30 to 75 days after planting. This could be attributed to the ability of FYM in rendering availability of other plant nutrients as well as chelation of humic substances in the soil. Particularly in the second season the effect of FYM became more vivid than in the first season. This could be explained by further decomposition of FYM and the residual effect by FYM in the subsequent season. These results are in line with those reported by Brady, (2008) that addition of 8 t FYM/ha increased sunflower plant height and number of leaves which in turn increased the surface area for photosynthesis.

Combination of nitrogen and FYM produced the tallest plants of all treatments. This is probably attributed to the improvement of rhizosphere environment and increased availability of nitrogen in the soil. These findings concur with those reported by Helmy and Ramdan, (2009) that, mixture of organic and inorganic fertilizers resulted in superior sunflower growth parameters including plant height and number of leaves compared to other treatments. Integrated application of organic and inorganic fertilizers has been previously reported to enhance growth of various crops including soya bean (Yagoub *et al.*, 2012).

The result of the study showed that; head diameter was not significantly affected by addition of nitrogen fertilizers, FYM alone or combination of both fertilizers. This shows that sunflower heads diameter is probably determined by varietal genetic composition. The diameter ranged from average of 14 cm to 18 cm in the first season. In this study control had 14 cm being the smallest head size, and 18.5 cm at 10 t FYM and 10 t FYM/ha +60 kg N/ha. Similar head sizes due to different nitrogen fertilization were also reported by Al- Thabet, (2006) that the head sizes ranged from 12 cm in control and 17 cm in 200 kg N/kg in Saudi Arabia.

5.2 Effect of nitrogen fertilizers, FYM and their combination on sunflower yield and yield components.

The results of the present study demonstrated that; during short rains of October to February, addition of nitrogen fertilizers, significantly increased plant biomass and seed yield. This might be due to the property of nitrogen in stimulating growth and yield components. Increase in seed yield due to application of inorganic nitrogen fertilizers was also reported by Al- Thabet, (2011) that, application of nitrogen fertilizers from 0 kg N/ha to 200 kg N/ha increased sunflower seed yield from 1 t /ha to 4 t/ha respectively.

Increase in sunflower seed yields due to application of FYM observed from this study was also reported by Rasool *et al.*, (2013) who found that sunflower seed yields were enhanced in the plots treated with FYM when compared to no - FYM plots; These findings are in agreement with previous studies by Sharma *et al.,* (1999) who reported that FYM increased plant height and seed yield in comparison to no – FYM control. This could be due to the fact that, decomposed FYM may have released the nutrients in the plant available form and also due to enhanced uptake of plant micronutrients like boron which has been reported by Sharma *et al.,* (1999) to improve sunflower growth and yield characteristics.

Ghalavand *et al*., (2011) further reported that, integrated inorganic and organic fertilizers resulted in the highest sunflower grain yield. These findings are at par with those reported by Munir *et al*., (2007) who also suggested that the positive combination effect might have resulted from the reduction of soil bulk density, increased water holding capacity and granulated soil structure which increases the efficiency of plant nutrients uptake. Sunflower achene yield was found higher in plots treated with FYM alone or in combination with chemical fertilizers than control in other studies (Esmaelian *et al*., 2012).

However, 10 t FYM/ha alone produced biomass yield of 108 % over the control. Similar biomass yield trend was reported by Rasool *et al*., (2013) in India. Significant effect of nitrogen fertilizers on dry matter weight could have resulted from the fact that; nitrogen is the principal constituent of proteins, enzymes, hormones, vitamins and chlorophyll, which contributes to improved leaf area index and increased dry weight. Several scientists have reported the effects of nitrogen fertilizers on sunflower dry matter formation; leaf area per plant and crop growth rate (Wabekwa *et al.,* 2012). Hussain and Thomas, (2010) additionally reported that nitrogen application significantly increased plant height and dry matter yields in sunflower crop. The two finding are in conformity with the report of Filho *et al.,* (2011); who found that application of nitrogen from

0 kg N/ha to 100 kg N/ha played a significant role in increasing sunflower stem, leaves and head dry weight in Brazil.

The increase in sunflower biomass formation from 10 t FYM/ha could be explained by the fact that FYM not only supply both of macro and micro nutrients in the soil but also improves soil physical conditions for better plant nutrient uptake hence increased growth and yields in field crops. Experiment conducted in Nigeria by Agele and Taiwo, (2013) on applications of FYM in sunflower crop production showed similar results.

In this study, weight of 1000 sunflower seeds was significantly affected by addition of fertilizers only during the short rains season probably due to the fact that high biomass produced might have remobilized and partitioned for grain filling and incidence of hollow seed formation was reduced.

The difference in 1000 seed weight between the two seasons could be attributed to severe crop lodging which occurred at early grain filling stage during the long rains season. It took place when assimilates had not been fully translocated to grain formation and this may have lowered the yields. HGCA, (2005) reported that, crop lodging can cause economic yield loss in cereal crops of up to 75% loss, depending on the crop growth stage at which lodging occurred. 80 % yield reduction was also reported by Tams *et al*., (2004) on field crops in United Kingdom (UK). Effect of yield loss due to crop lodging was reported by Sterling and Baker, (1998), Pinthus, (1973) and Berry *et al.*, (2004). 1000 Seed weight range obtained from this study (32 g to 52 g) is in line with the range that was reported by Ramulu *et al.*, (2011) who found out that weight of 1000 sunflower seeds were between 21 g to 60 g; the difference might also depend on genetic potential of the seed variety.

However, some findings also showed that; increase in 1000 seeds weight was not significantly affected by nitrogen fertilizers although weight increased as nitrogen rates were increased in Nigeria. Wabekwa, (2012) and Filho *et al.,* (2011) reported that; number of seeds per head as well as biomass, 1000 seeds weight was not significantly affected by nitrogen fertilization in Brazil. Additionally Nobre *et al*., (2014) reported a significant increase in 1000 seed weight due to application of nitrogen maximum being 44 g. Ebrahim *et al*., (2003) reported a significant increase of 1000 seeds weight due to application of nitrogen fertilizers in Sudan.

5.3 Effects of nitrogen fertilizers, FYM and their combination on sunflower seed oil content and total seed oil yield

The significant increase in sunflower seed oil content by application of 10 t FYM/ha (Table 10) could have resulted from beneficial properties of FYM in improving soil productivity and easy uptake of other nutrients like sulfur which has been reported to influence fatty acid formation processes on oil crops (Rasool *et al*., 2013).

The oil content trend reported from this study are supported by Ghalavand *et al*., (2011) who found that higher organic nutrition levels exhibited the highest levels of seeds oil content and as nitrogen accessibility increased, the seed oil content decreased.

Insignificant effect from the combination of FYM and UREA on increasing sunflower seeds oil content was contrary to other investigations which reported that; application of organic fertilizers and their combinations increased oil content over the control in Egypt (Helmy *et al.,* 2009). Similar results were also reported by Munir, (2007) who studied the effect of different fertilizer levels on sunflower oil content that combination and control treatments had higher and lower oil contents respectively.

The trend of 60 kg N/ha producing lowest oil content from both seasons might have been caused by sunflower crop lodging which occurred at early grain filling stage, 76 days after planting. Lodging has been reported to affect all crop yield components by HGCA, (2005) including seed oil percentage.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Application of fertilizers generally in sunflower production has showed a positive impact on crop growth, yield and yield components as well as percentage oil content. This is because this study found that; all fertilizer regimes applied from both sources gave higher response than the control. The trend of growth and yield results regarding the fertilizer sources showed that combination between 10 t FYM/ha and 60 kg N/ha showed the best result followed by FYM and finally nitrogen (Combination > FYM> Nitrogen). 10 t FYM/ha and the combination between 10 t FYM/ha and 60 kg N/ha played a significant role in sunflower seed yields and other yield components and gave the best results.

Lower levels of nitrogen 20 kg N/ha and 40 kg N /ha showed no significant effect on sunflower crop yields. Oil content showed peculiar behavior, which was only increased by the 10 t FYM /ha and control had higher oil content than some other treatments in both seasons. Yield data collected from long rain season of March 2014 to June 2014 were less reliable due to sunflower crop root and stem lodging which occurred during the reproductive stage.

6.2 Recommendations

As a result of the findings reported in this study, it is recommended that:

1. Farmers in Morogoro and Tanzania in general should consider application of fertilizers in sunflower crop production, especially 10 t of FYM alone and/or combination of 60 kg nitrogen and 10 t FYM as an important farm management practice to obtain seed yield of more than 1 t/ha.

   A similar study covering a wider range and higher fertilizer rates and their combinations to be conducted in order to determine their effect on growth, yield and oil content of sunflower crop. This is due to the fact there are studies where higher nitrogen levels of 150 to 200 kg N/ha were applied and registered yield as high as 4 t/ha.
2. A study to be carried out on the effect of organic and inorganic fertilizers on many more sunflower varieties rather than one variety (*record*).
3. A study on the economic returns in the use of fertilizers in sunflower production to be carried out to assess the profitability of the production system.

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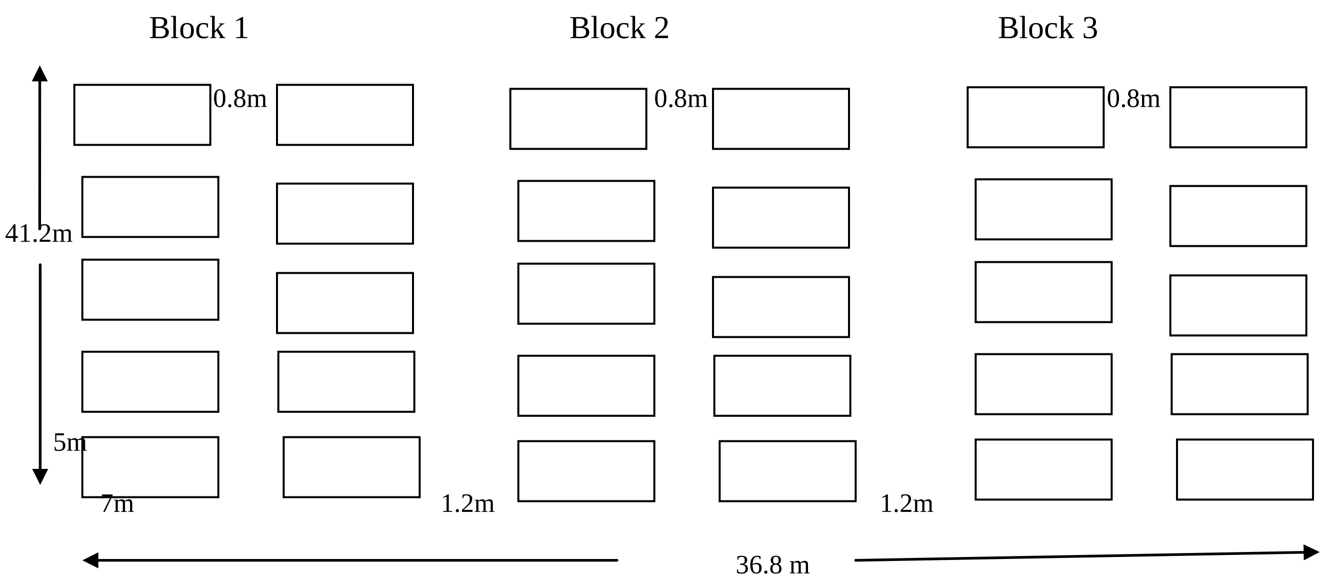
APPENDICES

Appendix 1: Weather data from Sokoine University of agriculture during the short and long rain seasons in 2013/2014

Month	Daily temperature ^{0}C Max	Min	rainfall (mm)	No. of rainy days	Relative Humidity (%)	Evaporation (mm)
October	31.5	19.4	70.5	9	46.29	5.1
November	33.5	19.4	33.9	6	42.33	7
December	30	20.8	22	6	45.74	7
January	32	22.1	0	0	40.39	8.7
February	31	22.9	69.4	8	54.55	5.6
March	32	22.3	129.5	20	57.61	4.4
April	30	21	224.7	20	77.03	3
May	29	19	113	17	67.37	2.8
June	29	16	24	2	58.4	2.6
July	31	20	13	1	52.68	3.4
Total			**700**	**89**	**542.39**	**49.6**
Average	**31**	**20**	**127.27**	**16.18**	**54.23**	**4.96**

Appendix 2. Field layout of an experimental plot



Total experimental area 36.8m * 41.2m = 1516.16m^2