KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

ORGANIC AND INORGANIC MICROFERTIGATION EFFECT ON THE GROWTH AND YIELD OF *AKPOSOE* MAIZE VARIETY

BY

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Bsc. Agricultural Technology (Hons)

A Final Thesis Submitted to the Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology, Kumasi in Partial fulfillment of the requirement for the degree

of

MASTER OF SCIENCE IN SOIL AND WATER ENGINEERING

College of Engineering

AUGUST, 2013

DECLARATION

I, Issaka Fuseini, hereby certify that, this dissertation is the outcome of my own research, carried out under the supervision of Dr. E. Ofori of Agricultural Engineering Department, Faculty of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi as a requirement for the fulfillment of the award of MSc (Soil and Water Engineering). I certify further that, no part or whole of this dissertation is a reproduction of another person's dissertation in the university or elsewhere. All materials which serve as sources of information have been duly acknowledged by their references.

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ACKNOWLEDGEMENTS

All praises and thanks are for **ALMIGHTY ALLAH**, the most grateful, the most merciful for granting me the guidance and protection throughout my education.

First of all, I am very grateful to my academic supervisor, Dr. E. Ofori of Agricultural Engineering Department of Kwame Nkrumah University of Science and Technology (KNUST) under whose dynamic supervision and encouragements this research work was presented as a thesis.

I also extend my utmost gratitude to Dr. W. Agyare of Agricultural Engineering Department for his expert advice, encouragement, knowledge sharing and assistance as my Second-Supervisor. My sincere gratitude also goes to Mr. K.F Kontor of Kwadaso Agricultural College for his fatherly assistance and granting me an experimental field where this project was carried out. Also, I am grateful to Mr. Daniel Ntiamoah Afreh, of Kwadaso Agricultural College for his support during the analysis of data from the study.

Also, to my wife, Fati Abubakar and my daughter; Ummi Zeinab Fuseini, for their prayers and support.

Finally, I acknowledge my dear parents Alhaji Issaka Dauda (Sariki Samarina Busangawa) and Mrs. Zeinab Issaka for their financial support and prayers throughout my education. I'm also grateful to my brothers and sisters for their support and prayers.

ABSTRACT

A research study was conducted at the arable field of the Kwadaso Agricultural College to evaluate the effect of liquid organic and inorganic fertilizer on the growth and yield parameters of *akposoe* maize. A total of three (3) treatments (organic, inorganic and organic+inorganic fertilizers) were applied in a completely randomized block design (CRBD) with no fertilizer treatment as a control. Fertilizer application was done based on the standard application rate of NPK 90:40:40 kg/ha. A total of 8.96kg/36 m^2 of organic fertilizer, 6.124kg/36m^2 of inorganic fertilizer and 7.54kg/36m^2 of organic+inorganic fertilizer combined were applied to a total of 192 plants/plot with no fertilizer application serving as control. Results from earlier soil analysis showed very high phosphorous content of the soil and for that matter fertilizer used did not contain phosphorous.

Data on growth parameters that were considered include; plant height, leaf length, leaf diameter, stem girth and number of leaves. Data was also collected on the grain yield of maize at 13% moisture content, above and below biomas as well as average root length. Data was subjected to analysis of variance using statistix8.0 analytical software. Treatments were observed to have performed better with combination of organic +inorganic fertilizer recording the highest grain yield of 6937.6kg/ha which was significantly different ($P<0.05$) than the rest of the treatments. At the end of the study, it was realized that the combination of organic+inorganic fertilizer for PVC drip fertigation improved the growth and yield parameters of akposoe maize. This will greatly benefit farmers in areas where the supply of inorganic fertilizer is low and also where farmers cannot afford the high cost of fertilizer input.

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LIST OF ABBREVIATIONS AND SYMBOLS

SSA	-	Sub Saharan Africa
IITA	-	The International Institute of Tropical Agriculture
CIMMYT	-	International Maize and Wheat Improvement Center
PUC	-	Polyvinyl Chloride
NPK	-	Nitrogen, Phosphorus, Potassium
SARI	-	Savanna Agricultural Research Institute
CEC	-	Cation Exchange Capacity
FAO	-	Food and Agricultural Organisation
PPM	-	Part Per Minute
ET	-	Evapotranspiration
EC	-	Electrical Conductivity
REP	-	Replication
CRBD	-	Completely Randomized Block Design
LL	-	Leaf length
PH	-	Plant height
SG	-	Stem girth
LD	-	Leaf diameter
NL	-	Number of leaves

CHAPTER ONE

1.1 Introduction

Maize (*Zea mays L*), also referred to as corn, is one of the most crucial and strategic crops in Africa and the developing world in general. It is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America. All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. Maize accounts for 30–50% of low-income household expenditures in Eastern and Southern Africa (IITA, 2008). It is produced in different parts of the African continent under diverse climatic and ecological conditions. In sub-Saharan Africa, excluding South Africa, the highest growth in maize area, yields, and production from 1961 over the entire period has been in West Africa, and the least has been in Southern Africa where yields have stagnated at a little over 1 t/ha (Alemu *et* al, 2007). Due to its increasing importance, maize has become a major staple and cash crop for smallholder farmers (FARA, 2009). It is estimated that by 2025, maize will have become the crop with the greatest production globally and in developing countries (CIMMYT and IITA, 2010) overtaking crops such as wheat and rice.

Maize is the most important staple crop in Ghana and accounts for more than 50 percent of total cereal production in the country (MoFA, 2012; MiDA, 2010).The bulk of maize produced goes into food consumption and it is arguably the most important crop for food security. The development and productivity of the livestock and poultry sectors could also depend on the maize value chain as it is a major component of their feed.

Maize is one of the most efficient grain crops in terms of water utilization, and thus can produce very high yields under irrigation. However, most maize production in SSA is produced under rainfed conditions. Occasionally maize is grown under irrigation in areas with warm and dry periods (e.g. semi-arid areas) to ameliorate the effects of drought. In peri-urban areas, where maize is normally grown for the fresh market, irrigation is used for out-of season production (FiBL, 2011). Experience has shown that the most appropriate and suitable irrigation scheme for small-scale farmers is the drip system. In drip irrigation, water is applied only to the soil around the maize roots, so that it can easily be accessed. This means less water is needed and therefore water is efficiently used. When irrigation water is limited, irrigation scheduling should be based on ensuring that the maize plants have enough water so as not to dry out during flowering. Irrigation will reach higher efficiency only if it is combined with good measures for improving the soil structure and water retention of the soil. However, the productivity of most agricultural lands in Ghana is declining at an alarming rate due to widespread land degradation caused by soil erosion, deforestation, soil nutrient mining, uncontrolled bush burning and other poor management practices (NMTIP, 2005). As farmers cannot afford the high cost of mineral fertilizer, improved soil fertility management strategies such as both on-farm and off-farm organic sources of plant nutrients (e.g. farmyard manure, farm waste, crop residues, green manuring) will have to be promoted. This will provide alternative source of fertilizer whenever there is high cost orun availability of inorganic fertilizers.

In view of the growing human population, there is the need for sustainable agricultural production. The intensification of production through the use of high-yielding varieties – with the associated high demand for fertilisers, pesticides and irrigation combined with intensive soil tillage– has led to a remarkable increase in crop yields, but also to serious environmental problems as regards soil fertility and biodiversity decline. This is alarming because biodiversity and soil fertility are essential to the sustainable functioning of the agricultural, forest, and natural ecosystems on which human life depends. As an alternative to these high input systems, farmers and researchers have developed organic farming systems which rely more on the use of recycled organic fertilisers such as manure and manure compost derived from the farm.

The sustainability of any production system requires optimum utilization of resources such as water, fertilizer and soil. Because of its highly localized application and the flexibility in scheduling water and chemical applications, drip irrigation has gained widespread popularity as an efficient and economically viable method for fertigation. Drip irrigation with fertigation offers a high potential for optimum utilization of water and fertilizers (Raina *et al*, 1999). Application of fertilizers through an efficient irrigation system, known as fertigation, results in more accurate and timely crop nutrition, thus, leading to increased yield besides considerable savings in fertilizers (Bussi *et al*, 1991). Fertilizers applied under traditional methods are generally not utilized efficiently by the crop due to wrong method of application, wrong timing and above all, lack of skills in fertilizer application. In fertigation, nutrients are applied through emmiters directly into the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application. Generally, crop response to fertilizer application through drip irrigation has been excellent and frequent nutrient applications have improved the fertilizer-use efficiency (Malik et al, 1994). The crop response to fertilizer applications is expected to vary markedly with the type of fertilizer used.

Maize crop responds very well to water and nutrient application. Maize is one of the amenable crops for drip irrigation system, which is an efficient method of irrigation. Scientists reported enhanced growth and development of maize under drip irrigation (Lamm et al, 2001).

Maize growth under drip irrigation gave better results in terms of growth parameters as compared to rain-fed ("No irrigation") (Asenso, 2012).

Fertigation is a relatively new but revolutionary concept in applying fertilizer through irrigation. It helps to achieve both fertilizer-use efficiency and water-use efficiency. The benefits of fertigation have been examined in several studies. Much of the studies relates to fertigation in commercial crops. Papadopoulos 1988, have stated that crop yields under fertigation have greater yield potential than previously imagined. A properly designed drip fertigation system delivers water and nutrients at a rate, duration and frequency, so as to maximize crop water and nutrient uptake, while minimizing leaching of nutrients and chemicals from the root zone of agricultural fields (Gardenas et al., 2005).

Studies on drip fertigation are very limited. Input information on optimal schedules for micro-irrigation and fertigation to maize will have to be generated from this current study to provide insight into micro-fertigation under maize cultivation. Therefore, the present investigation was conducted to study the performance of *Akposoe maize* as influenced by organic and inorganic micro-fertigation using a locally designed PVC drip irrigation system.

1.2 Problem Statement

There is an increasing demand for maize in Ghana and inorganic fertilizer use has been the major means of achieving higher yield. However, the cost of chemical fertilizer is expensive for the small scale farmers who constitute over 80% of the Ghanaian population. In situations where farmers can afford to buy the fertilizers, the ti mely availability is an issue of concern. Also, granular fertilizers do not immediately affect plants, since it may take a long time for positive results to show, hence low nutrient use efficiency. Plants may not receive nutrients fast enough to help them recover from deficiencies. The pH of soil may also adversely influence their effectiveness.

Inappropriate application of granular fertilizer lives telltale streaks and spots of burned leaves on crops, since the applications of granular fertilizer must be done when the likelihood of a significant rainfall is high, or when irrigation or tillage can be used to incorporate it into the soil. Urea broadcast on moist soil should have 0.5 inch of rain (Meyer et al, 1961) or irrigation in one event within a couple of days to dissolve prills and move urea deep enough into the soil to minimize volatilization. Over the years the application of fertilizer has been done through the broadcasting method, side placement, band placement etc. There is very little information on the application of fertilizer using drip irrigation system.

With the abundance of organic fertilizers with no commercial value placed on them and the increasing demand for organic produce due to the high nutrient value, less contamination and also presence of needed trace elements, it has become necessary to carry out a comparative study on organic and inorganic fertilizers and how the application of each of them impact on the growth and yield of *Akposoe* maize using a simple PVC drip fertigation system.

1.3Objectives

1.3.1 General Objective

The general objective of the project was to compare the effect of organic and inorganic drip-fertigation on the growth and yield of *Akposoe* maize.

1.3.2 Specific Objectives

The Specific Objectives of the Research Study were:

1. Evaluate the performance of *Akposoe* maize as influenced by organic and inorganic drip fertigation (growth and yield)
2. To quantify the effects of organic and inorganic fertilizers and their combinations on plant nutrient uptake and crop yield
3. To recommend effective ways of supplying fertilizer to maize plant using a drip irrigation system

1.4 Justification

Maize is a major cereal crop and an important constituent of local dishes in West Africa and for that matter Ghana. It is not grown only for local consumption and for forage but also for export to earn foreign exchange. Farmers do apply fertilizer and irrigate their crops as separate practices which are both labor and capital intensive. However, nutrients can be supplied effectively to maize plants using a simple PVC drip irrigation system. The successful implementation of the project will help make available to farmers the use of simple drip irrigation system due to their inability to purchase conventional drip irrigation system. Hence, the need for this study.

1.5 Limitation

- An unexpected wind storm that damaged some of the crops.
- Pests attack during the late stage of crop growth.

1.6 Delimitations

- The study was conducted on an area of 240 m^2
- *Akposoe* maize variety with a maturity period of 80-85 days was used for the study.
- Organic and inorganic fertilizer containing NPK were used at the recommended standard application rate of 90kgN, 40kgP and 40kg K.
- The study concentrated only on the growth and yield parameters of *Akposoe* maize.

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

Maize (*Z. mays L.*) is a tall, monoecious annual grass with overlapping sheaths and broad conspicuously distichous blades. Plants have staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelets occur in 8 to 16 rows, approximately 30 cm long, on a thickened, almost woody axis (cob). It is generally agreed that teosinte (Z. mexicana) is an ancestor of maize, although opinions vary as to whether maize is a domesticated version of teosinte (Galinat, 1988). *Zea* is a genus of the family Graminae (Poaceae), commonly known as the grass family. The whole structure (ear) is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971).

Maize is cultivated worldwide and represents a staple food for a significant proportion of the world's population. No significant native toxins are reported to be associated with the genus Zea (International Food Biotechnology Council, 1990).Maize is the most important cereal crop produced in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO, 2008; Morris *et al*., 1999). In Ghana, maize is produced predominantly by smallholder resource poor farmers under rain-fed conditions (SARI, 1996).Maize grains have great nutritional value as they contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983).

2.2 The Maize Plant

The maize plant may be defined as a metabolic system whose end product is mainly starch deposited in specialized organs, the maize kernels. The development of the plant may be divided into two physiological stages. In the first or the vegetative stage, different tissues develop and differentiate until the flower structures appear. The vegetative stage is made up of two cycles. In the first cycle the first leaves are formed and development is upward. Dry matter production in this cycle is slow. It ends with the tissue differentiation of the reproductive organs. In the second cycle the leaves and reproductive organs develop. This cycle ends with the emission of the stigmas.

The second stage, also known as the reproductive stage, begins with the fertilization of the female structures, which later develop into ears and grains. The initial phase of this stage is characterized by an increase in the weight of leaves and other flower parts. During the second phase, the weight of the kernels rapidly increases (Tanaka and Yamaguchi, 1972).

2.2.1 Varieties of Maize

Maize can be classified into the following types according to the characteristics of the endosperm. These are dint maize, flint maize, flour maize, popcorn, pod corn flint-dent maize. Zea consist of five species, including cultivated *Zea mays* and four wild relatives, all from America referred to as Teosinte. Zea mays are heterogeneous species and cultivars can be divided into eight types or cultivar groups according to the structure and shape of the grains;

- Dent maize (indintata); it is soft and white.
- Flint maize (indurate); flinty is hard starch.
- Popcorn (everata)
- Pod corn (tunica)
- Sweet corn (saccharata)

2.2.2 Importance and Uses of Maize

Maize is a component of canned corn, baby food, hominy, mush, puddings, tamales, and many more human foods.

Some industrial uses of maize include filler for plastic, packaging, materials, insulating materials, adhesives, chemicals, explosives, paint, paste, abrasives, dyes, insecticides, pharmaceutical, organic acids, solvents, rayon, antifreeze, soaps, and many more.

In sub-Saharan Africa, maize is a staple food for an estimated 50 % of the population and provides 50 % of the basic calories. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals.

Most Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season.

2.2.3 Soil Conditions Necessary for Maize Production

Maize thrives in well drained sandy loam soil in regions with rainfall not less than 500-800mm evenly distributed throughout the growing season for good yield. Deep fertile soils rich in organic matter and well-drained soils are the most preferred ones. However maize can be grown on a variety of soils. Soils should be medium textured with good water holding capacity. Loam or silt loam top soil and silt clay loam having fairly permeable sub soil are the ideal soil types. Maize Crop is very sensitive to water logging. The pH should be between 6.5 to 7.5 along with CEC of 20 meq/100g and base saturation of 70 to 90 %, bulk density of 1.3 g/cc water holding capacity of about 16 cm per meter depth. The soils of the major maize growing areas in Ghana are low in organic carbon (<1.5%), total nitrogen (<0.2 %), exchangeable potassium (<100 mg/kg) and available phosphorus (< 10 ppm) (Adu, 1995, Benneh *et al*. 1990).

Maize is mainly grown under conventional agricultural practices for years. The basis of conventional tillage is annual ploughing or tilling of the soil, but this is usually supplemented with a number of other practices, including the removal or burning of crop residues, land leveling, harrowing, fertilizer application and incorporation, etc. All of these practices cause soil disturbance, and can lead to compaction, and deterioration. Ploughing enhances the rapid breakdown of soil organic matter. The soil collapses and compacts, reducing aeration and the number of soil organisms. The top soil becomes susceptible to erosion and runoff, so that after heavy rainfalls a great deal of soil is lost and little water is retained, leading to shallow and infertile soils which are no longer able to produce good yields.

2.2.4 Nutrient Requirement of Maize

Daily measurements of growth and consumption of nutrients by the maize plant was reported by André *et al.* (1978) for various physiological stages: vegetative, female and male flowering period and cob development. From seed development to male flower appearance, transpiration is at constant ratio with photosynthesis. After silking (female flower), cobs and seed formation takes place with a continuous decline in daily water consumption. On day 62 of maize growth (maximum N uptake), a single plant consumes140 mg N and 254 mg K (Kafkafi and Tarchitzky, 2011). The plant continues to take up N and K until harvest at about 20% of the maximum rate. Plant uptake fluctuates on a daily basis even if grown in a nutrient solution that is renewed daily during the entire experimental period. Plant demand for N is controlled by the internal plant metabolism of the various developing organs at any specific time.

The plant's physiological stages are important in planning for fertigation such that water and nutrients are supplied to the roots to meet plant demand. If the root volume is limited such as in containerized planting in greenhouses, the frequency of water and nutrient renewal must be kept daily. In field grown maize, it is important to follow the root volume distribution for irrigation timing and nutrient supply.

The root volume under trickle irrigation is relatively small, compared to a whole soil volume under sprinkler or surface irrigated crops (Sagiv *et al.*, 1974). This requires that crops growing on poor sandy soils receive a continuous supply of water and mineral nutrients during the entire plant growth cycle, from seeding to harvest. The basic knowledge of nutrient supply to crops under fertigation stems from early physiological studies on plant nutrition using hydroponic media (Benton-Jones, 1983).

The role of fertigation is to deliver plant nutrients from fertilizers with irrigation water to the root surface in sufficient quantities to prevent deficiencies during plant development. Supplying the right amounts of water and plant nutrients daily at the right time to meet plant needs is crucial in preventing excess supply of plant nutrients and seepage of nitrate salts to underground aquifers. Precise fertigation can prevent aquifer pollution and is less costly to farmers.

The timing of irrigation affects water and nutrient distribution in the soil. Ben-Gal and Dudley (2003) showed that in a sandy soil with very low P sorption capacity, the highest P concentration was found down to 10 cm below the dripper. With the same amount of water, but with continued application, P is found below 25 cm. Irrigation frequency also influences the water content and pH of the soil. It is to be expected that in heavy clay soils, the distribution of nutrients from a point source differ from that in sandy soil (Bar-Yosef, 1999). From the viewpoint of P uptake or dry matter production, the exact P distribution in the soil is not important as can be deduced from the data of Ben-Gal and Dudley (2003). As most of the P is taken up by maize during grain formation and maturity, late application of P with low N and K levels might secure high grain yield with low water application, but with daily P application in small quantities. Such a combination could save water pollution and fertilizer wastage. A detailed study on water uptake by maize with surface and subsurface drip irrigation was reported by Coelho and

Or (1996), who found that root distribution follows water distribution in the soil in both irrigation systems. The highest yield of *Akposoe* maize was obtained by applying water at 20 cm depth (Asenso, 2012).

2.2.5 Climatic Requirement of Maize

Maize crop is a warm weather loving crop and it is grown in wide range of climatic conditions. Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than19 °C or where the mean of the summer temperatures is less than 23 °C. That is, the crop tolerates a wide range of environmental conditions, but grows well in warm sunny climates with adequate moisture (Purseglove, 1992).

Maize cannot withstand frost at any stage. Maize can successfully grow in areas receiving an annual rainfall of 60 cm, which should be well distributed throughout its growing stage. Crop needs more than 50% of its total water requirements in about 30 to 35 days after tasseling and inadequate soil moisture at grain filling stage results in a poor yield of shriveled grains.

Maize needs bright sunny days for its accelerated photosynthetic activity and rapid growth of plants. Prolonged cloudy period is harmful for the crop but an intermittent sunlight and cloud of rain is the most ideal for its growth.

Temperature

The optimal average temperatures for maize growth range between 20 and 23°C. However, the optimum temperature varies over the maize growing season and between daytime and nighttime.

Maize can survive short exposure to low and high temperatures of 0 and 44°C, respectively. Cooler temperatures slow down the growth of plants. Growth decreases once temperature drops to about 5°C.

Extremely low temperatures cause freeze damage, the severity of which will depend on the temperature, duration, and maize growth stage. Extended low temperatures at seedling stage that reduce the soil temperatures to below freezing two inches below the surface may kill maize.

Later in the season, a long exposure of maize to temperatures below -2°C can damage corn by damaging the "growing point". The growing point for corn is located in the center of the stem and below the soil surface until the V5 - V6 growth stage (5 - 6 corn leaves with collars). At the V6 growth stage, maize would be approximately 30.48cm tall. It is important to remember that although corn can germinate and grow slowly at about 10°C, the planting should start when the average soil temperature reaches 13°C at the top 5.1cm. Poor germination and stand usually are the result of low soil temperatures.

Maize yield may also be reduced due to high air temperatures (35°C and higher) during pollination. High temperatures during this time can cause damage to pollination if plants are under drought stress. During moisture stress, especially at low relative humidity, high temperatures can desiccate silks and damage or kill pollen. Pollination will not be affected by high temperatures if there is adequate moisture in the soil, because pollen shed usually occurs during morning hours.

Crop Water Requirement of Maize

The crop water need (ET crop) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

In general, maize needs at least 500-700mm of well-distributed rainfall during the growing season. Even the amount of rain may not be enough, however, if the moisture cannot be stored in the soil because of runoff or shallow soil depth, or if the evaporative demand is very large due to high temperature and low relative humidity (ARC-Grain Crops Institute, 2003). Approximately 10 to16kg of grain are produced for every millimeter of water used. A yield of 3152kg/ha requires between 350 and 450mm of rain per annum. At maturity, each plant will have used 250 litres of water in the absence of moisture stress (ARC-Grain Crops Institute, 2003).

The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need depends mainly on:

- The Climate: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- The Crop type: crops like maize or sugarcane need more water than crops like millet or sorghum
- The Growth stage of the crop; fully grown crops need more water than crops that have just been planted

Maize is a quick, vigorous, and tall growing crop having broad leaves, therefore its water requirement is exceptionally high. A vigorous growing maize plant requires about 2-3 liters of water per day during peak growing period or an average consumptive use of water varying from 2.5 to 4.3 mm (FAO, 2007). Maize is known to be susceptible to water logging as well as soil moisture stress due to drought. Since flowering and grain-filling stages are most critical, the crop should not be moisture stressed at these stages. Timely availability of moisture through irrigation is one of the major factors determining the success of the crop. Where soils are generally light, it is desirable to schedule the irrigations at 70%soil –moisture availability through the period of crop growth and development. In heavy soils, moisture level of 30% during the vegetative stage and 70% during the reproductive and grain-filling period is desirable for obtaining optimum yield (FAO, 2009).

2.3. Fertilizer Types and Usage

Fertilizer is any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more plant nutrients essential for the growth of plants. Conservative estimates report 30 to 50% of crop yields are attributed to natural or synthetic commercial fertilizer (Stewart et al, 2005).

Fertilizers are broadly divided into organic fertilizers (composed of organic plant or animal matter), or inorganic **or commercial fertilizers**. Plants can only absorb their required nutrients if they are present in easily dissolved chemical compounds. Both organic and inorganic fertilizers provide the same needed chemical compounds. Organic fertilizers provided other macro and micro plant nutrients and are released as the organic matter decays—this may take months or years. Organic fertilizers nearly always have much lower concentrations of plant nutrients and have the usual problems of economical collection, treatment, transportation and distribution. For organic fertilizers Nitrogen, Phosphorus and Potassium compounds are released from the complex organic compounds as the animal or plant matter decays.

Inorganic fertilizers nearly always are readily dissolved and unless added have few other macro and micro plant nutrients nor added any 'bulk' to the soil. Nearly all nitrogen that plants use is in the form of NH_3 or NO_3 compounds. The usable phosphorus compounds are usually in the form of phosphoric acid (H_3PO_4) and the potassium (K) is typically in the form of potassium chloride (KCl). In commercial fertilizers the same required compounds are available in easily dissolved compounds that require no decay—they can be used almost immediately after water is applied. Inorganic fertilizers are usually much more concentrated with up to 64% (18-46-0) of their weight being a given plant nutrient, compared to organic fertilizers that only provide 0.4% or less of their weight as a given plant nutrient. Inorganic fertilizer use has also significantly supported global population growth — it has been estimated that almost half the people on the Earth are currently fed as a result of synthetic nitrogen fertilizer use (Erisman et al, 2008).

2.3.1 Organic Fertilizers

Organic fertilizers have become increasingly popular and far more effective in recent years. Many studies have demonstrated that application of manure will produce crop yields equivalent or superior to those obtained with chemical fertilizers (Xie and MacKenzie, 1986; Motavalli et al., 1989).Organic fertilizers are loaded in natural, plant based proteins. The Impact of Organic range has been reformulated for 2012 and is now solely based on vegetable proteins and does not contain any genetically modified products. Organic products are now predominantly produced from soybean meal, which is high in protein and an excellent choice for improved overall plant health and increased growth.

Natural proteins are slow in terms of nutrient release. They are first broken down into amino acids by microbial activity. These amino acids are then broken down further to ammonium ions and, ultimately nitrate ions. Swards that thrive in acidic soil react well to nitrogen provided as ammonium ions. It is this form of nitrogen which helps these proteins to develop. Organic fertilizers contain seaweed meal which adds valuable micronutrients, growth hormones, and vitamins which help disease tolerance, reduce plant stress from drought, and increase frost tolerance. Organic fertilizers contain formulations suitable for fine turf, as well as for fairways and outfields. These formulations contain a balance of quick release nitrogen, phosphate and potassium (NPK) for an initial response from the plant. This initial release is followed by further response from the methylene urea and a sustained release from the plant proteins.

Advantages of Organic Fertilizer

- **All natural**

Organic fertilizers usually composts are made by decomposing biodegradable wastes. These wastes may include paper, leaves, fruit peelings, leftover foods and even fruit juices. These are all natural and the process of decomposing them needs no chemicals either. An abundance of worms are all it takes to decompose these wastes and turn it into organic fertilizer. One does not have to worry about build up of toxic wastes because that does not happen with an all natural source of ingredients.

- **Make the soil rich**

Organic fertilizers make a good addition to the soil. They make the soil rich and ideal for planting. With a good soil, plants will get the nutrients that they need. Furthermore, organic fertilizers do not upset the balance in the soil as they do not leave behind any artificial compounds.

➢ **Transform unhealthy soil**

Adding organic fertilizers to sandy and clayey soils improves the content and quality of the soil making it more suitable for planting.

➢ **Correct imbalances**

As the soil goes through the cycle of planting and harvesting and de-cropping, it becomes stripped bare of nutrients and the pH balance is also affected as well. Organic fertilizers help correct these imbalances in soil pH to make it more suitable for plant growth.

Nutrients are delivered slowly in small increments as the organic fertilizer is slowly breaking down. Plants do not get shocked by a sudden high dose of nutrients being delivered that comes with using inorganic fertilizers. Over fertilization which can be harmful to the plants can be avoided. Furthermore incidents where the roots get burned from direct application of high doses of fertilizer can also be avoided.

➢ **Cost- effective**

The raw material needed to make an organic fertilizer can be found even in our homes. Biodegradable wastes can be recycled and turned into compost.

Disadvantages of Using Organic Fertilizers

➢ **Takes longer time to release nutrient**

Some plants grow sick and are malnourished and at times at the verge of dying. Some are even on the verge of dying. At this point, plants need an immediate intervention. Meaning they need high doses of nutrients fast. This is possible with the use of an inorganic fertilizer but not with an organic fertilizer. The slow and sustained release of nutrients by the organic fertilizer cannot be made to hasten in order to meet the needs of a dying plant. If you wait for the organic fertilizer to release everything it has stored, the plant may die during the long wait. Zhang et al. (1998) found that 2 kg manure-N were equivalent to 1 kg of urea-N in terms of plant uptake and yield response during the first year following cattle feedlot manure application.

- **High demand, low supply**

If you have a big garden it is advisable to use organic fertilizers so that it will not be too costly. However, organic fertilizers enough for a big garden is not readily available. While you can make your own organic fertilizer by composting, you really need a lot to fertilize a big garden. The wastes from the house can only make so much organic fertilizers that it is not enough. Furthermore, it takes a while to prepare organic fertilizers.

- **Simple but messy and inconvenient**

It is very simple to make compost. There are even a lot of recipes for organic fertilizers available. However, whipping it up can get messy not to mention it may also give unpleasant odour from the rotting of the organic ingredients. A lot of people find making compost far more problematic than what it's worth. Hence, they'd rather pay a price for a little bit of convenience.

Organic fertilizers indeed offer a lot of benefits but they have their drawbacks as well. Better consider the pros and cons before deciding on which path to take.

2.3.2 Inorganic Fertilizers

Inorganic fertilizers have synthesized elements and formed into fertilizer that has an exact amount of stated nutrient. As such, it costs considerably more than organic fertilizers. Inorganic fertilizers usually contain three major nutrients (i.e Potassium, Phosphorous and Nitrogen) that plants need to grow and survive. These are usually seen in the label itself, and one can immediately tell by looking at the bag the percentage of nutrients found in the fertilizer. Based on the primary fertilizer content (N, P, K), fertilizer is given a name consisting of three parts. This relation demonstrates the quantity of Nitrogen (N), phosphate (P), and potassium (K) content of the fertilizer in terms of its weight percentage

Inorganic fertilizers nearly always are readily dissolved and unless added have few other macro and micro nutrients. Nearly all Nitrogen that plants use is in the form of NH_3 or NO_3 compounds. The usable Phosphorus compounds are usually in the form of Phosphoric acid (H_3PO_4) and the Potassium (K) is typically in the form of potassium chloride (KCl). In commercial fertilizers the nutrients are available in easily dissolved compounds that require no decay. They can be used almost immediately after water is applied.

Advantages of Inorganic fertilizer

- **Works immediately**

Inorganic fertilizers are usually given as a ''rescue treatment'' to plants that are malnourished, unhealthy or even dying. Inorganic fertilizers are appropriate in this situation because the nutrients needed by the plants are readily available. In comparison, using an organic fertilizer would mean that the plant has to wait until the components of the organic fertilizer have been broken first into its primary nutrients. By then, the plant could be dead already.

- **Contains the major nutrients that are ready to use**

Inorganic fertilizers are designed to give plants the major nutrients-Nitrogen, Phosphorous and Potassium that they need in appropriate proportions and amounts. Hence, plants do not get more of one kind of nutrient than the other. Instead it has a balance of all the nutrients it needs and are readily available at a given time.

- **Convenient to use**

It takes a while to make your own organic fertilizer. Though the process is relatively easy to do, still you need to dedicate enough time to do the task and wait for the decomposition part to take place. With an inorganic fertilizer, you save a lot of time and effort.

Problems with inorganic fertilizer

- **Water pollution**

The determination of nitrate levels in surface waters is an integral part of basic water quality assessment because its concentration is generally an indicator of the nutrient status and the degree of organic pollution of the water body. Regular monitoring of nitrate for in drinking water is recommended because of the potential health risks associated with its elevated levels, especially for infants below six months old and animals (Gray, 1994).

Nitrates are released into the soil and water through a breakdown of naturally occurring organic nitrogen compounds through mineralization, hydrolysis, and bacterial-activated reactions (Nalan, 1999 and Speriran, 1996). Urea like other forms of organic nitrogen in soil and natural waters is converted to ammonia under anaerobic microbial processes (Speriran, 1996). Ammonia is also converted to nitrate and nitrite which are soluble in water both of which do not bind to soil and have high migration potential through soil. Consequently, nitrates are washed easily into surface waters by rain or leached through soil into ground water. Plant cover, land use, fertilizer pattern, fertilizer usage, soil type, rainfall pattern, irrigation, climatic conditions, and depth of ground water below land surface are the main factors that control the leaching of nitrates as well as nitrites.

- **Fertilizer dependency**

Effectively farmers unknowingly became 100% dependent on 'bought in' water soluble, inorganic fertilizers since the sterilization of soil microflora including its mycorrhiza, reduced the availability of other natural and trace minerals within the soil. This to some extent explains the resurgence of interest in organic and particularly 'biodynamic' farming systems since these systems replace the essential soil organisms so essential to converting soil minerals into plant available (but rarely water soluble) nutrients (Khan, et. al ,2009). They do this by a variety of processes including chelation whereby essential minerals become plant available - as measured by weak citric acid extraction technique. Hence the citric acid solubility of phosphate rocks has emerged as a measure of plant availability and enabled the so-called 'reactive' phosphate rocks to be used as fertilizer minerals.

2.3.3 Factors influencing farmers' adoption and intensity of fertilizer use

Demand and supply factors are hard to separate when evaluating farmers' decisions to adopt fertilizer and their subsequent decisions about application rates.

Key influences are:

- Farm size,
- Access to credit,
- Membership in cooperatives,
- Contact with extension,
- Access to outside information,
- Availability of inputs

2.4 Drip Irrigation system

Drip irrigation is the frequent, slow application of water to the soil through mechanical devices or holes called *emitters* (drippers or applicators) located along the water delivery line. This eliminates spraying or running water down furrows and supplies filtered water under low pressure directly onto or into the soil. Water is carried through a pipe network to each plant. Emitters dissipate the pressure in the pipe distribution network by means of either a small-diameter orifice or long flow path, thereby decreasing the water pressure to allow discharge at low volumes of water per hour. After leaving the emitter, the water is distributed by its normal movement through the soil profile. Therefore, the area that can be wetted from each emitter is limited by the water's horizontal movement in the soil. The objective of drip irrigation is to supply each plant with sufficient soil moisture to meet transpiration demands. Drip irrigation offers unique agronomic, agrotechnical and economic advantages for the efficient use of water (Harrison, 2012).

2.4.1 Advantages of Drip Irrigation

The main advantages of drip irrigation are:

1. It allows maximum beneficial use of available water supply by controlling water flow to allow maximum crop yield with high water use efficiency
2. Evaporation losses are minimized since water is discharged at or below ground level
3. Pressure requirements are low resulting in lower operating costs
4. Labor requirements are usually lower than with most other types of irrigation
5. Irrigation water can be applied during farm operations.
6. Fertilizers and other agro-chemicals can be applied through the system.
7. Plant protection from diseases and insects is improved by not wetting plant leaves
8. Reducing the wetted area limits weed growth and restricts populations of potential host pest

2.4.2 Disadvantages of Drip Irrigation

Although drip irrigation offers several advantages for the grower, the system has some disadvantages, problems and limitations.

1. The water supply must be free of soil particles to function properly. Adequate and dependable filtering system is most often difficult to provide

2. Emitter clogging can result from poor water filtration, algae, bacteria, sulfur, iron and calcium in the water. This can lead to non-uniformity of water discharged from the emitters causing additional complications
3. On sandy soils, drip irrigation does not provide adequate water distribution. The water does not tend to move laterally; therefore, insufficient root volume is wetted causing high water use and leaching of nutrients
4. Mice and other animals sometimes chew on the flexible plastic pipes, causing considerable damage.

2.5 Fertigation

Fertigation is the application of dissolved nutrients by means of an irrigation system (Magen, 1995). Although the practice of fertigation only started commercially in the mid-20th century, there is evidence that the concept of irrigation with dissolved nutrients was well known in the past. The first reported example dates back to ancient Athens (400 B.C) where city sewage was used for the irrigation of tree grooves (Young and Hargett, 1981).

Fertilization contributes to the achievement of higher yield and better quality by increasing fertilizer efficiency (Haynes, 1985; Imas, 1999), regardless of whether DI or SDI is being used. Advances in micro-irrigation techniques have facilitated greater adoption of the application of fertilizers to crops through irrigation water. If fertilizers are applied through irrigation systems, savings of 29–78% in application costs may result due to the improved efficiency of fertilizer application, low fertilizer leaching, precise nutrient application, and right-amount and right-time fertilizer application. Although no significant increases in crop yield have been reported (Alva et al. 2005), uptake of major plant nutrients, i.e., Nitrogen, Phosphorous, and Potassium, is higher with fertigation than with conventional methods (Papadopoulos, 1988).

The main purpose of fertigation is the maximum production of good quality fruit by means of optimal utilization of water and fertilizer, as well as the manipulation of plant physiologic processes to ensure optimal vegetative growth. These production objectives (yield and quality) are determined by the market for which production is done and are influenced by the fertigation programs followed. The soil or medium in which cultivation is done, is used as storage or buffer (the soil's resistance to drastic chemical changes) from which the plant can absorb fertilizers freely. A fertigation program is compiled, considering the fertilizer contribution of the irrigation water and the soil's nutritional balance. The compound of irrigation water and chemicals, as well as the chemical and physical interactions between soil or medium, can however seriously influence the ability of the soil or medium to act as buffer. Fertigation is more important in cases of sandy, gravelly, or stony soil with low nutritional retention ability, as well as chemically poor-balanced soils and irrigation water combinations. The used of localized wetting irrigation systems, e.g. drip irrigation systems, has the result that less dependence is needed from the soil's provision and buffering ability.

2.6.1 Methods used in fertigation

- Drip irrigation, which reduces per water and nutrient application rates relative to sprinklers
- Sprinkler systems, which increase leaf and fruit quality
- Other methods of application include lateral move, traveler gun, and solid set systems
- Continuous application - fertilizer is supplied at a constant rate
- Three-stage application - irrigation starts without fertilizers and then the later in process fertilizers are applied
- Proportional application - injection rate is proportional to water discharge rate
- Quantitative application - nutrient solution is applied in a calculated amount to each irrigation block

All systems should be placed on a raised and/or sealed platform, not in direct contact with the earth, and fitted with chemical spill trays. In order to determine the injection rate for the particular fertilizer being used, one should use the formula:

Maximum injection rate = $(5 \times Q \times L) / (f \times 60)$

where Q = irrigation pump discharge in liters per second, L = fertilizer tank volume in liters, and F = amount of fertilizer in grams.

2.6.2 System design

The simplest type of fertigation system consists of a tank with a pump, distribution pipes, capillaries and dripper pen.

➢ **What should be considered?**

- Water quality
- Soil type
- Nutrient consumption (daily)
- Appropriate nutrient materials

➢ **Possible strategies to be used**

- Injecting for short time-periods at the beginning, middle, and end of irrigation cycle
- Injecting during middle 50% of the irrigation cycle
- Continuous irrigation
- Postering index Imex

2.6.3 Types of fertilizer products

Fertilizer products are available in water soluble granular, powder or liquid form. The choice between the different types will depend on the storage space available, the available injectors, product stability, ease of handling, injection method, cost and the acidification possibility of the fertilizer.

The compilation of a fertigation program will mostly be the result of the production objectives of the producers, the physiological stage of the crop, the chemical composition of the irrigation water and the soil, as well as the irrigation system in use. Two concepts are at hand when referring to fertigation. The first is when fertilizer products are applied by means of an irrigation system. A time scale is applicable here, e.g. the nutrients can be applied annually, weekly or even daily. This approach does not mean that the nutrient must be present in the irrigation water each time that irrigation is applied. Single elements, such as only nitrogen, or a combination of elements, such as a combination of Nitrogen, Phosphate or Potassium can be applied together. In general, the shorter the time scale, the more balanced, more expensive and more plant absorbent the fertigation program should be. With localized wetting irrigation systems e.g. drip systems, the crop usually has an intensive localized root system. The nutritional supplement must be given at short intervals, e.g. by maintaining continuous nutritional balances within the root zone. The second approach is that water for irrigation must be enriched with nutrients every time irrigation is applied, completely balanced nutrients elements must be present. This approach is referred to in general as the hydroponic approach.

Fertilizer concentration can be indicated as kg or litre per ha, kg or litre per cubic meter irrigation water and electrical conductivity (EC) at or without a certain pH. Electrical conductivity (EC) is an indication of the irrigation water's natural salt content and the composition of the fertilizer mixture. If a certain quantity of a given fertilizer product is applied in water, it will indicate a certain electrical conductivity value. This value is proportional to the quantity of the product in the water and EC can therefore be used to control the quantity of nutrients that is applied. The ideal water-pH, with which irrigation is applied, is between 5.6 and 6.2, because in this pH series, elements are the most absorbent by plants (Kafkafi and Tarchitzky, 2011). Plants adapt to a certain pH and EC and a large deviation therefrom causes plants to use the energy which it should have used for production, to adapt to new conditions. This results in accompanying reduction or discontinuance of growth and production. It is exactly the approach to expose plants to constant EC and pH levels as far as possible with the open system. Hydroponic can lead to maximum production that is not possible by other methods.

- **Nitrogen**

Nitrogen is the element mostly required and therefore applied the most. A suitable N concentration is dependent on the production objectives and crop requirements. Movement of Nitrogen through the soil and absorbency of the Nitrogen source depend on the type of Nitrogen source and percentage available Nitrogen in the source.

At low application levels, ammonium ($NH4^+$), which is positive and therefore adsorbs on the negative clay particles, will result, thus the movement thereof is limited in the soil (Kafkafi and Tarchitzky, 2011). As soon as ammonium application is increased and the exchangeable capacity of the soil is overcome, the movement of ammonium through the soil will also increase at a rate which is dependent on the soil type. At a soil temperature of 25°C to 30°C, the ammonium will be biologically transformed to a nitrate (NO_3^-). This process is called nitrification. If the soil remains too wet as a result of irrigation or rain, the transformation will occur very slowly as a result of a lack of Oxygen. Where the soil and irrigation water has a pH of 7 or higher, ammonium will transform into NH_3 (ammonium gas) and an N-loss can occur by means of volatility. The solubility of urea is good, is not easily absorbed by the soil and therefore moves into the soil easily- deeper than e.g., ammonium. After the hydrolysis from urea to ammonium, the reactions will be the same as discussed for ammonium.

Nitrate (NO^-_3) is negatively loaded exactly as clay particles and therefore the antagonism has the result that the NO^-_3 ions are not strongly bound to the soil particles. The NO^-_3 ions usually move to the edge of the wetted area (Kafkafi and Tarchitzky, 2011). Any form of applied nitrogen, will eventually be transformed to a nitrate form in the soil and the nitrogen application should therefore take place either periodically or through the irrigation water, or by means of water enrichment on a permanently balanced manner. Except for leaching, denitrifying can result in great N-losses. During the process, NO^-_3 changes to volatile N-forms. This usually occurs when there is too much water and consequently too little oxygen in the soil. Effective scheduling is therefore a prerequisite to ensure maximum yields under nutritional fertilization.

If NH^+_4 ions are dominant in the soil, H^+ ions will be withdrawn from the root zone, which will lead to the acidification of the soil solution. The amount of calcium-carbonate required to neutralize the acidity of a specific fertilizer type, is called the calcium carbonate equivalent. When the NO^-_3 ion is mainly absorbed, HO^- or HCO^-_3 ions will be released with a consequent increase in the pH of the soil solution. High soil-pH will reduce the availability of zinc, iron and phosphates for the plant.

- **Phosphate**

The nutritional phosphate-requirements of a crop are the highest during the germination phase or directly after planting. If the water pH (>7.5) and especially water with bicarbonate (HCO^-_3) as well as the Ca and Mg content is high, sediments of Ca^{2+} and Mg^{2+} phosphates occur very fast. With certain reservations, phosphoric acid can be applied, but the pH must be monitored closely. This must however not be done without the advice of a professional. An incorrect recommendation can result in sedimentation with consequently the total blockage of the entire system. Where pH and the amount of Ca^{2+}, Mg^{2+} and HCO^{-}_3 ions are low, very few problems will be experienced with P applications. A low pH (<5.5) for long periods, can, in the long run, increase the possibility of corrosion of metal equipment and damage the plant roots.

- **Potassium**

Potassium seldom causes problems such as blockages and precipitates within irrigation lines. The most general sources of potassium, namely potassium sulphate (K_2SO_4), potassium chloride (KCl) and potassium nitrate (KNO_3) are reasonably soluble in water and will not cause serious problems. Potassium nitrate (KNO_3) is reasonably soluble in water and will not cause serious problems. It moves in the xylem vessels as a cation, balanced mainly by nitrate (Ben Zioni *et al.*, 1971). Potassium sulphate and potassium nitrate are preferred over potassium chloride, especially with crops which are salt-sensitive. As soon as the potassium is applied, the K cation, K^+, will adsorb on the clay particles. When the exchange complex of the clay is saturated, the K^+ can descend reasonably easily and move sideways in the soil.

- **Micro elements**

Micro elements or trace elements are plant nutrient taken up by plants in very small quantities, but fulfill an essential role in the physiology of the plant. In the absence of one or more of these elements, normal growth and reproduction is affected. When a micro-element is deficient, plants show obvious deficiency. The most important micro-elements which are essential for the normal development of the plants are iron, manganese, boron, copper, zinc and molybdenum.

2.6.4 Choice of fertilizer products

Some irrigation water and fertilizer product-combinations can cause detrimental reactions such as corrosion and precipitation (resulting in blockages). It is therefore recommended that a jar test is first done by adding the fertilizer at the correct concentration to the irrigation water. Monitor the mixture for sediments or milkiness over a period of one or two hours. Milkiness will be an indication that blockage problems are possible. Secondary filters at each block can protect the emmiters against the potential damage. With the choice of fertilizer products, the following must be kept in mind:

- When a dry water soluble fertilizer is used, first fill the tank halfway to three quarters with water and then add the fertilizer slowly while stirring the water continuously to prevent the forming of large insoluble lumps. Always add the liquid fertilizer to the water in the tank before the dry water soluble fertilizer is added, to ensure the solution of all the fertilizer products.
- Fertilizer products that have an acid base, are inclined to cause corrosion of metals. Ensure that the injection and irrigation equipment is resistance to these products.
- Not all fertilizer products are compatible in concentrate form, e.g. products which contain sulphate, are incompatible with products that contain calcium. The result will be the formation of insoluble gypsum. Phosphates are also incompatible with

products that contain calcium and magnesium. These products must be injected separately from different tanks into an irrigation pipeline.

2.6.5 Monitoring water, soil and plant during fertigation

Fertigation is an advanced tool that provides the farmer with a precise instrument for fertilization and irrigation according to plant requirements and soil or growth media conditions. In order to take advantage of the agro-technical benefits of fertigation, very close monitoring of irrigation water, soil and growth media, drainage and crop is recommended.

2.7. Monitoring the quality of irrigation water

The objectives of sampling and analyzing the irrigation water are (Kafkafi and Tarchitzky, 2011).

- Evaluate its suitability for a specific crop, soil, irrigation method, filtration degree and other necessary chemical treatments;
- Determine salinity level and concentration of toxic elements in the water to assess their effect on crops;
- Determine sodium concentration and sodium absorption ratio (SAR) to assess the potential long-term effect on soil structure and water infiltration;
- Determine the nutritional value in order to take into account the nutrients in the water that is used in the fertigation programme.

Salinity in irrigation water is defined as the total sum of dissolved inorganic ions expressed in units of mol per litre or total weight of salt in grams per litre of water. The main components of salinity are the cations; calcium (Ca), magnesium (Mg) and sodium (Na), and the anions; chloride (Cl-), sulfate (SO_4-) and bicarbonate (HCO_3^-).Nitrate (NO_3) and Potassium (K) are usually minor components of salinity. Boron (B) and other dissolved micronutrients are negligible in assessing the salinity of irrigation water. Salinity is simply measured by determining the electrical conductivity (EC) of the water. Sodicity or Na hazard of irrigation is related to soil dispersion, soil structure breakdown, potential for water infiltration problems, and accumulation of Na in plants. The most common procedure to evaluate the potential damage by Na is the Sodium Adsorption Ratio (SAR). The presence of HCO_3^- reduces the activity of Ca in the solution and, therefore, taking its concentration into the calculation of cation activities in the water gives a better assessment of the reduction in Ca concentration in the soil solution by changes imposed on the solubility of Ca compounds. Element toxicity problems in the irrigation water are different from those of the salinity problem, and normally occur when certain ions are being taken up by the plants during transpiration and accumulated in the leaves to a level that result in leaf damage (Kafkafi and Tarchitzky, 2011).

2.7 Monitoring in soil and growth media

- **Soil:** For crops grown in soils, soil sampling and testing are essential tools to manage soil salinity and determine nutrient supply. By means of soil tests, deviation between prevailing and optimum concentrations can be determined and corrective measures undertaken to restore required concentrations in the soil.

Monitoring nutrient status in soils can be achieved by two approaches (Bar-Yosef, 1992). The first involves soil sampling at a reference position in the root zone and extraction to determine soluble and sorbed nutrient concentrations in the soil. The second, for NO_3^- and Cl^- only, is to sample the soil solution directly by means of vacuum cups inserted permanently in the soil and to analyze the collected solution. Frequency of sampling depends on the soil type, water quality and crop growth stage. Example, for orchards, sampling twice during the year can be enough but, if relatively high salinity water is used, sampling should be done every 3-4 weeks in order to monitor soil salinity and to decide about leaching dose applications. In intensive crops like vegetables, the soil should be sampled frequently (every 2- 3weeks) in order to monitor both the nutrient concentration in the soil and salinity, and eventually to correct the fertilization programme or to leach accumulated salts. Instructions for soil sampling of the Israeli Extension Service (Tarchitzky and Eitan, 1997) are as follows:

- **Drip irrigation:** The sample is taken along the drip lateral, at a distance of 10 cm from the dripper, to depths of 0-30, 30-60, 60-90 cm. About 20 random samples are taken from a plot of 2000 m^2.
- **Sprinkler and micro-jet:** The distance of sampling from irrigation accessories is selected according to the discharge and water distribution of the emitter, i.e. distance of 70-100 cm from a micro-jet or 100-120 cm from a mini-sprinkler or a sprinkler. Samples are taken from depths of 0-30, 30-60, 60-90 cm, with about 20 random samples from a plot of 2000 m^2.

In general, all the samples from the same depth are mixed well in order to obtain a representative composite sample. Each composite sample of a certain depth is placed in a separate bag, and about 1 kg is sent to the laboratory. Identification of the sample includes name, address, plot number, crop, depth and date of sampling. The extraction methods are specific for nutrient and the soil characteristics (Hagin *et al.*, 2002). Water-soluble nutrients are usually determined in saturated-paste soil extracts and sorbed nutrients by specific extractants (Bar-Yosef, et al., 1992). Potassium is often measured by the extraction of the exchangeable fraction or an expression that relates to the soluble K and divalent cations to the exchangeable phase as Potassium Adsorption Ratio (PAR). The analyses have to be calibrated with results from field experiments on crop response. Soil tests for estimation of the "available P" present in the soil are used as a guide in decision making on P fertilizer additions via the trickle lines. Because of the immense variability in the estimation of available P by soil testing methods and the different extraction methods used by soil test laboratories all over the world, each location has developed its own method of estimation of soil available P. Intensive vegetable and glasshouse production systems usually disregard the levels of P detected in soil tests and use a complete nutrient solution during the whole growing period to make sure that deficiency is avoided. Plant analysis is preferred in intensive growing under trickle irrigation, where only part of the soil is wet and the root volume represents only a small fraction of the total soil volume.

2.8 Monitoring the plants

Visual nutrient deficiency symptoms are used as a diagnostic tool (Scaife and Turner, 1983; Winsor *et al.*, 1987). A high level of expertise is a prerequisite for a valid diagnosis. A disadvantage of such observation is that, by the time the symptoms appear, damage to the plant has already been established and the deficiency might be serious, and correction of it is too late to avoid yield decrease. Plant tissue analysis shows the nutrient status of the plants at the time of sampling, whether nutrients supplied to the root solution are adequate or may confirm visual deficiency symptoms. Toxic levels also may be detected. Plant tissue analysis allows correction of present nutritional problems or can act as a tool for a future fertilization programme. Dry matter and nutrient content determination in plant tissues is tedious, destructive and needs laboratory facilities. In annual and short growing season crops, like field crops, vegetables and flower plantations, the analyses need to be done very quickly. To be effective in correcting present deficiencies, the analyses must be completed within two to three days after plant sampling.

In fruit trees, leaf analysis is a common tool for nutritional guidance, the plant tissue analysis is used to prepare a future fertilization programme, and a longer time period is available to complete the analyses in the laboratory. Deducing fertilizer recommendations from plant tissue analyses data is not always straightforward. Concentrations of plant nutrients in tissues change with the physiological age of the tissue. Air humidity, temperature and soil moisture affect the concentration of nutrients by influencing transpiration and solute transport in the plant as well as the plant growth rate. Very strict standardization of plant tissue sampling is therefore necessary (Hagin *e t al.* , 2002).

However, comparing samples from both a "good" and a "bad" area any time in the growing season often helps in taking corrective actions. The parts of plants to sample depend on the plant and its growth stage. Tissue sampling techniques for selected field crops, vegetables, ornamentals and flowers, fruit and nut trees have been developed (Flynn *et al.*, 1999). The following nutrients can be determined in a plant sample: nitrogen (N), phosphorus(P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), boron (B), sodium (Na), chloride (Cl) and other micronutrients. The leaf or whole plant samples have to be taken at optimal periods according to the specific plant standards. Instructions for petiole or leaf sampling may differ.

2.6.6 Selection of an irrigation system for fertigation

Irrigation systems are selected based on their water use efficiency, which varies with the soil properties and crop characteristics rather than the application system itself. Irrigation systems are categorized by their irrigation efficiency, defined as the volume of water beneficially used by the plants relative to the volume delivered by the system (Jensen, 2007). Sprinkler and drip systems have substantially high irrigation efficiencies (60–70% and 80–90%, respectively) than that of traditional surface flooding (50–60% efficiency) (Nir, 1982; Smajstrla *et al.*, 1991). Flood irrigation techniques utilize more water compared to low-volume, pressurized irrigation systems. In flood irrigation, the water is directed and controlled by constructed basins, borders, and/or furrows. During flood irrigation, the applied water percolates through the plant root zone, resulting in losses of applied nutrients to leaching. On the other hand, low-volume irrigation systems apply water only to the soil around the plants; therefore, agrochemicals can be more effectively applied with such systems. Because the infiltrating water dispenses the fertilizer in the soil, fertilizer distribution depends on the water flow pattern in the particular soil (Hanson et al. 2006). Under flood irrigation, most of the water movement is due to gravity, resulting in excessive drainage. More nutrients may be needed for flood-irrigated fields than those irrigated with low-volume systems (Thompson et al. 2000), which retain the applied water, and hence the nutrients, in the plant root zone (Fares and Alva 2000). Pressurized irrigation systems offer the ability to use high-frequency fertigation (Boman and Obreza, 2002). High irrigation water application efficiency associated with negligible deep percolation in drip irrigation systems makes them ideal for fertigation. Because drip irrigation systems apply controlled and precise amounts of water to the field, negative impacts (i.e., surface runoff, soil erosion, deep percolation, and nutrient loss) are avoided. Prescribed chemical application, reduced application cost, reduced operator hazard, no soil compaction, and less plant injury are among the important advantages of fertigation through drip irrigation systems compared to foliar fertigation via above-ground sprays (Vieira and Sumner, 1999).

2.6.7 Future trends in fertigation

Fertigation was first developed for field and horticultural crops, and later used on tree plantations. In later times, small gardens and the potting trade adopted the use of fertigation with automatic scheduling of irrigation cycle for home and city gardens. Fertigation today is used in many systems, small or large scale, all over the world. The shortage of water worldwide for use in agriculture and increased urbanization has forced agricultural development to new locations, less suitable to old flood or canal irrigation methods (Kafkafi and Tarchitzky, 2011). While large flat areas use center pivot systems and combine it with N fertilizers, new plantations on hilly terrains have become more and more fashionable for vineyards and tree plantations. Under these growing conditions, complete nutrient feed is expected to dominate since soil volume available for tree growth is small compared to the old system of deep soil plantations. In arid areas, the shortage of potable water and increase of population is driving farmers to use any available water source. Two main avenues of development are possible, the use of recycled city sewage water and desalination of either sea or recycled water (Kafkafi and Tarchitzky, 2011). Desalination of recycled water can prevent the accumulation of salts in the tilth layer, but energy cost limits its use. Sodium chloride accumulation in the irrigated area under recycled water is the main problem, as long period of usage of such water source can reduce soil productivity. Bringing arid lands into cultivation can be sustainable only if good quality water is available for agricultural production. Trickle irrigation and fertigation will continue to expand and slowly replace traditional flood irrigation wherever population demand for fresh water put pressure on water resources. This will free a significant amount of water to be used by the urban population. Labor costs are also an important factor in the transformation from flood or canal irrigation to permanent fertigation systems. As agriculture progresses from subsistence to commercial, the shift to fertigation is inevitable.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study Area

The study was conducted at the Vegetable Garden of the Kwadaso Agricultural College, Kumasi. The area is about 6-7Km from the main central business area of Kumasi. The soil is typically of the Forest Ochrosol series with tropical climatic conditions.

3.1.1 Geology and Soil

The soil of Kwadaso is classified as well drained, sandy clay loam, moderately coarse textured. The pH of the soil is between 5.0 and 5.5 which is good for proper growth and development of crops such as cowpea (*Vigna unguiculata*), maize (*Zea mays*), tomato (*Brassica olericea*), garden egg (*Solanum melongena*), okra (*Abelmoschus esculentus)*, cabbage (*Brassica olericea*), pepper (*Capsicum Annuum*)

3.1.2 Vegetation and Climate

The area is characterized by two (2) rainy seasons; a major rainy season from April to July and a minor season from September to October. The month of August experiences a short dry season. Temperature varies between 26^0C and 34^0C. The area has scattered trees which shed their leaves especially during the dry season. The common scattered trees are *Acacia fistula, Acacia seamia, Adansonia digitata, Mangifera indica* and some grasses such as *Andropogon spp, Panicum maximum* and *Cyperus rotundus*.

3.2 Methodology

3.2.1 Research Design

The research was carried out using field experimentation on an area of $240m^2$

Randomised Completely Block Design (RCBD) with four (4) replication. Each experimental plot was $"1.5m \times 6m = 9m^2$. Each plot had three rows with 16 plants per row and a plant spacing of $75cm \times 35cm$. Length of field was restricted by the length of PVC pipe which was 6m. Each pipe had sixteen (16) holes. The size of the drip holes was 2mm spaced at a distance of 0.35m. One plant was planted per hill resulting in a total of 768 plants for the study.

The treatments were as follows;

T_1 = Organic Fertilizer (Natural Asontem+ ACM humic) NPK =6.4N:0P:3.5K)

T_2 = Inorganic Fertilizer (Sidalco Liquid Fertilizer) N: P: K = 6N:0P:20K)

T_3 = Control (No Fertilizer Application)

T_4 = Organic + Inorganic Fertilizer Application

Table 1: Field Layout of Experiment

REP 1	REP 2	REP 3	REP 4
T_1= Organic	T_2= Inorganic	T_3=No fertilizer	T_4=Org+ Inorg
T_2= Inorganic	T_3=No fertilizer	T_4=Org+ Inorg	T_1= Organic
T_3=No fertilizer	T_4=Org+ Inorg	T_1= Organic	T_2= Inorganic
T_4=Org+ Inorg	T_1= Organic	T_2= Inorganic	T_3=No fertilizer

3.2.2 Materials for the Study

Materials used for the study were as follows:

- Liquid organic and inorganic fertilizers
- Maize(certified seeds planted as test crop)
- Installed simple PVC drip irrigation system
- Spirit level
- Measuring tape
- Cutlass
- Hoe
- 100 litre plastic container
- Weighing scale
- ½ inch (0.0127m) PVC pipe 6m in length
- ½ inch internal diameter (0.0127m) end caps
- ½ inch internal diameter (0.0127m) elbow
- ½ inch internal diameter (0.0127m) tap
- 2 mm drill bit
- 2 mm drill machine
- Wooden stand
- Electronic scale(Kern EMB 500-1) with a capacity of 1200 g

3.2.3 Soil Sampling

Soil samples were collected from each block at the beginning of the research. The sampling depths were 0-15cm and 15-30cm.In all, a total of eight samples were taken randomly across the entire field per sampling depth and then bulked to one sample to eliminate variability before the analysis.

3.2.4 Land Preparation and Planting

Land preparation was done by clearing the entire land of vegetation by spraying with *Adwuma wura* weedicide containing Glyphosate 41%SL. The weedicide was applied at the rate of 1.5l/ha so as to control and reduce dominant weeds on the field. A. Valtra tractor was used to plough and harrow the field to obtain good seed- bed for planting. This was followed by the demarcation of the entire field into four (4) separate blocks. Each block was further divided into four (4) plots for the four (4) treatments. Treatments were randomly selected and placed in the blocks.

3.2.5 Arrangement of Simple PVC drip Irrigation system.

A total of forty eight (48) PVC pipes of length 6m each and diameter 22.5 mm were used. Drip holes of diameter 2mm were made at a spacing of 0.35m on each PVC pipe based on maize planting distance (0.35m x 0.75m). The drip holes were drilled with a hand drill machine with a drill size of 2mm. Three laterals were connected to a main line which was connected to a hundred (100) litre water container (Figure 1). A total of 4 of the 100l container were used with each container assigned to a treatment. The height of the container relative to the junction of the main lateral was one meter (1 m). End caps were used to cover one end of the pipe line to prevent water flowing out and improve pressure build up in the pipe. 3-way connectors or Elbows were used to connect the extension pipes to the main lateral. Three (3) of these laterals with a total area of nine ($9m^2$) were connected to the hundred (100) litre water tank which served as one treatment (Figure 1). Each set of drip irrigation system arrangement with a total of forty (48) drip holes was discharging hundred (100) litres of water in ten (10) minutes (60seconds). The PVC pipes were placed at a distance of 0.4cm to the base of each plant to supply fertilizer and water to the plant.

3.2.6 Calibration of flow in PVC drip irrigation system

To obtain a uniform flow of water from the PVC drip laterals with a length of 6m, the pipes were calibrated to determine;

- Quantity of water from each drip hole.
- Flow variation in each drip hole under the 100L, 1m head setup.

$$Flow\ rate = \frac{100L}{10} minutes\ = 10\ litres(L)/minute$$

To calibrate the pipe for uniformity of flow, three laterals made up of 48 drip holes of 2mm diameter were used. Each lateral of 6m was fixed with an end cup at one end, a three (3) way connector and an elbow fixed at the other end and joined to a pipe of height 1m. This was connected to the main pipe through the elbows to supply water from the storage tank to the main laterals through the drip holes. Collector cans were used to collect water from the drip holes. The collector cans were placed on a leveled surface which was checked with a leveling device (spirit level), to ensure even distribution of water in the drip holes. A hundred (100) liter container was used as the storage tank and placed at a height of 1m to provide the flow head. Water was discharged into the hundred (100) litre via an overheard tank installed at the vegetable garden of the Kwadaso Agricultural college. The tap connected to the tank was opened fully to allow the water flow through the three (3) laterals. The collected water over 10min was measured using a measuring cylinder. Uniformity of water flow from each drip hole was assessed.

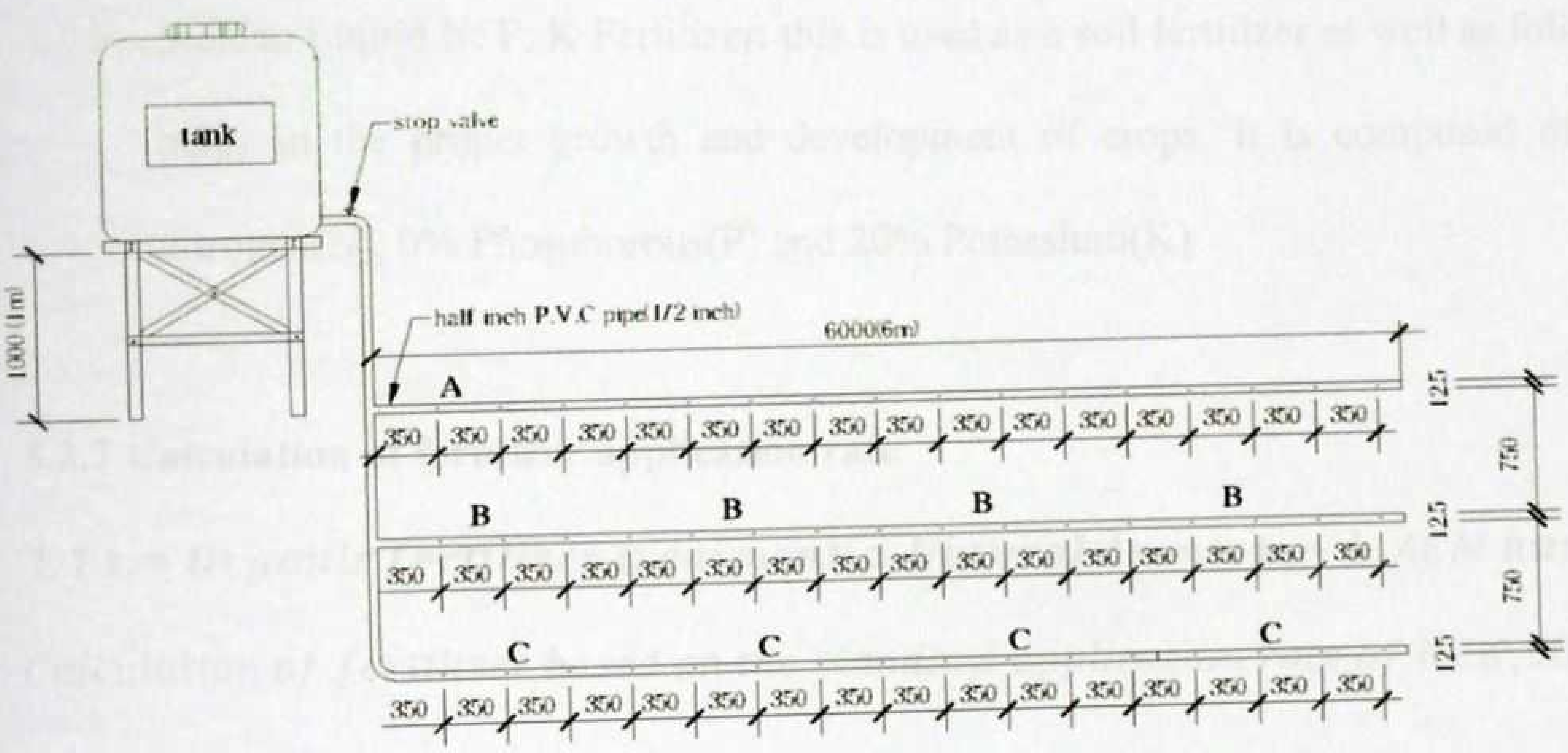

Figure 1: Diagram of the drip fertigation system

3.2.7 Description of fertilizer

- Natural Asontem Organic Fertilizer: this is indicated for biological organic agriculture. It brings organic nitrogen and stimulates the growth of the plants and regenerates the bacteria flora. It also helps the assimilation of the fertilizers associated to it. It is composed of 6.4% w/w organic nitrogrn and 22%ww organic carbon. It is produced by AGRIA sri CCIAA. Ragusa 70716-Italy and marketed in Ghana by K. Badu Agro Chemicals Company.

- ACM-HUMIC organic fertilizer: it stimulates soil microflora. Assist in the development of microbial colonies. Promotes the germination capacity of seeds, improve energy processes in plants, stimulates root development and increases crop production. It is composed of 15% Humic acid, 3.5% K_2O with trace elements. It has a pH of 13 and a density of $1.15g/cm^3$. It is produced by Agro Conculting Del Mediterraneo, S.LK and marketed in Ghana by PGM Agro services.
- Sidalco Liquid N: P: K Fertilizer: this is used as a soil fertilizer as well as foliar. It helps in the proper growth and development of crops. It is composed of 6% nitrogen(N), 0% Phosphorous(P) and 20% Potassium(K)

3.2.7 Calculation of fertilizer application rate

$\mathbf{1.\,T1 = Organic\ fertilizer\ treatment(a.\,Natural\ Asontem + b.\,ACM\ humic)}$

$Calculation\ of\ fertilizer\ based\ on\ the\ standard\ application\ rate\ of\ NPK, 90{:}\,40{:}\,40kg$
$/ha$

$a.\,Composition\ of\ Natural\ asontem\ organic\ fertilizer = 6.4{:}\,0{:}\,0kg/ha$

$Net\ weight\ of\ natural\ asontem\ organic\ fertilizer = 1kg/0.8litres = 1000g/\ 0.8$ litres

$$1000g\ of\ fertilizer \times 6.4\% \frac{N}{100} = \frac{64gN}{kg}\ fertilizer$$

$$= \frac{64gN}{0.8\ litres} of\ organic\ fertilizer$$

$$Considering\ standard\ application\ rate\ of \frac{90kgN}{ha} = \frac{90kgN}{10000m^2}$$

$$Elemental\ experimental\ area\ for\ Nitrogen\ application = 36m^2$$

$$Therefore, 0.324kgN = 324gN\ was\ required\ for\ a\ plot\ area\ of\ 36m^2$$

$$Number\ of\ litres\ of\ fertilizer\ for\ 324gN/36m^2$$

$$0.8/\ litres\ of\ fertilizer\ contains\ 64gN$$

$$therefore\ 4.05\ litres\ of\ fertilizer\ was\ required\ to\ supply\ 324gN/36m^2$$

b. *Composition of ACM humic organic fertilizer*

$$1. Net\ weight\ of\ ACM\ humic\ organic\ fertilizer = \frac{1.10kg}{litre}$$

$$1100g\ ACM \times 3.5\% \frac{K}{100} = \frac{38.5g}{1.1kg} fertilizer$$

$$\frac{38.5g}{1.1kg}\ fert \times \frac{1.10}{litre} = 42.35gK_2O/litre$$

$$NB: \frac{42.35gK_2O}{litre} = 0.0423kgK_2O/litre$$

$$conversion\ of\ K_2O\ to\ K$$

$$42.35gK_2O \times 0.83 = \frac{35.15gK}{litre} = 0.035kg/litre$$

$$considering\ application\ rate\ of\ \frac{40kg}{ha}\ and\ with\ experimental\ plot\ area\ of\ 36m^2$$

$$\frac{144gK}{36m^2} = 0.144kgK/36m^2$$

$$number\ of\ litres\ of\ fertilizer\ to\ give \frac{144gK}{36m^2} = 4.0561litres$$

$$C.combination\ of\ Natural\ Asontem + ACM\ Humic = 4.05 + 4.096 = 8.146\ litres$$

2. T_2= (Inorganic Fertilizer treatment)

$$calculation\ based\ on\ the\ standard\ application\ rate\ of\ NPK: 90: 40: 40Kg/ha$$

$$Net\ weight\ of\ sidalco\ liquid\ fertilizer = lkg$$

$$1. Amount\ of\ nitrogen\ N\ needed\ for\ an\ area\ of\ 36m^2$$

$$Rate\ of\ application = 90kgN/ha(10{,}000m^2)$$

$$To\ supply \frac{90KgN}{36m^2} = \frac{36}{10000} \times 90kg = \frac{0.324KgN}{36m^2} = 324g/36m^2$$

$$But\ fertilizer\ contains\ 6\%N$$

$$= \frac{100}{6} \times 0.324 = 5.4kgN/36m^2$$

$$1Kg\ of\ fertilizer = 1\ litre$$

$$now\ number\ of\ litres\ of\ fertilizer\ to\ supply\ 5.4KgN = 5.4litres$$

$$1. Amount\ of \frac{Potassium\ K\ needed}{36m^2}$$

$$Rate\ of\ application = \frac{40kgK}{ha\ 10{,}000m^2}$$

$$therefor\ to\ supply \frac{40kgK}{36m^2} = \frac{36}{10{,}000} \times 40kg = \frac{0.144kgK}{36m^2} = \frac{144g}{36m^2}$$

$$But\ fertilizer\ contains\ 20\%K$$

$$= \frac{100}{20} \times 0.144 = 0.724kg = \frac{720g}{36m^2}$$

$$therefore\ if\ 1kg\ of\ fertilizer$$

$$= 1litre, then\ number\ of\ litres\ to\ supply\ 0.724kgK = 0.724litres$$

$$= 724ml$$

$$NB: Total\ amount\ of\ fertilizer\ to\ supply\ 5.4litres\ of\ Nitrogen\ and\ 0.724litres\ of\ K$$

$$= 5.4 + 0.724 = 6.124\ litre\ of\ Sidalco\ liquid\ fertilizer$$

3. T_3= No fertilizer Application

The third treatment was administered without fertilizer. Only irrigation water was supplied to the plants during the treatment application period.

4. T_4 = (Combination of Organic + Inorganic Fertilizer)

From the above calculations, four (4) litres of organic fertilizer and three (3) litres of Sidalco liquid fertilizer (7.542kg/ha) were combined as the fourth treatment. Therefore, total number of bottles of fertilizer used in treatment four (4) was seven bottles of both organic and inorganic fertilizer.

3.2.8 Mixing of fertilizer with irrigation water

Quantity of fertilizer to be supplied to each treatment plot at a particular time was calculated and applied accordingly. Before fertilizing the plant, the liquid fertilizer was first mixed with about five (5) litres of the irrigation water to serve as a stock solution before adding to the final water to be made available to the maize plants.

A Hundred (100) litre irrigation tanks (4 pieces) with the capacity to deliver 100 litres of water in 10 minutes was used during treatment application. The fertilizers were mix thoroughly with water in the tank before discharging to the respective plots. Treatments were applied a week after germination, and on the fifth week after germination.

Figure 2: Arrangement of treatments on the field

3.2.9Experimental Procedure

Certified seed maize of *Akposoe* variety was obtained from the Crop Research Institute, Kwadaso and was planted on 22ndMarch, 2013. Planting was done at the rate of two (2) seeds per hill and later thinned to one plant per hill. Application of liquid organic and inorganic fertilizers of N and K sources were done at the rate of 60kgN/ha and 40kgK/ha, using simple PVC drip fertigation system.

Hoeing was done three (3) times at three weekly intervals after planting to control post-emergence weeds on the field. Supplementary irrigation was done using a simple PVC drip irrigation setup with emitters spaced according to the planting dimension (35cm× 75cm). Each emitter was delivering approximately 2.0 litres of water in six (6) minutes.

3.3 Performance Criteria

The following performance criteria were used in ensuring the uniformity in distribution of drip irrigation was carried out.

3.3.1 Flow Variation

Emitter flow variation Qvar was calculated using the equation:

Flow variation,

$$Qvar = 100 \times \frac{(Qmax - Qmin)}{Qmax} = \frac{100(2.5-1.5)}{2.5}$$

$= 40\%$

Where:
Qmax = maximum emitter (drip hole) flow rate

Qmin = minimum emitter (drip hole) flow rate

3.3.2 Uniformity Coefficient

Uniformity coefficient, $UC = 100 \times \left[1 - \frac{\left(\frac{1}{n} \sum_{i=1}^{n} \left| q_i - \bar{q} \right| \right)}{\bar{q}} \right]$

Where: q = Discharge

$\bar{q}$ = Mean of Discharge (q)

n = Number of (drip holes) emitters calculated

Uniformity coefficient, $UC = 100\left[1 - \frac{3}{48}(1.89)\right]$

$= 100[1 - (0.0625 \times 1.89)]$

= 100 (1-0.118)

= 88%

3.3.3 Coefficient of variation

$$CV = \frac{S}{q} = \frac{0.198}{1.89} =$$

Where: S = Standard deviation of emitter flow rate

Q = Mean of Discharge

$CU = \frac{0.198}{1.89}$

= 10.5%

3.4 Data Collection

Data was collected on both the growth and yield parameters of maize. Each treatment had three (3) rows with a total of forty eight (48) plants. Five middle plants from each treatment in a replicate were randomly selected, tagged and data constantly collected from these plants. Data was collected continuously on the five (5) middle plants weekly from the second week after germination till the 9th week when data collection was brought to an end.

3.4.1 Growth parameters of *Akposoe* Maize

Some major growth parameters of the maize were observed and measured on weekly basis till the final growth stage of the plant. Data collected included: Number of Leaves

(NL), Leaf Length (LL), Stem Girth (SG), Leaf Height (LH) and Plant Height (PH). The yield parameters considered were fresh cob weight, dry cob weight, Number of seeds. Plant heights were measured from the soil surface to the highest point of the arch of the uppermost part of the maize plant with a 16 feet measuring tape. The leaf length was measured using a 30cm measuring rule from the point of attachment of the leaf to the tip of the leaf. Stem girth were measured using a nylon rope which was wrapped around the stem and readings recorded accordingly. The leaf diameter was also measured using the 30cm measuring rule. NB: ruler was gently moved along the width of the leaf until the highest width was attained and subsequently recorded. Number of leafs were counted and recorded accordingly. NB: dead leafs were not considered during counting.

3.4.2 Yield Parameters

Yield parameters of maize were recorded after the maize plant has reached its final growth stage. The cobs were harvested after the maize plant had achieved complete dryness. Each tagged plant was harvested and put into a black polyethylene bag. The five 'tagged plants from each treatment were then kept in a fertilizer sack and labelled accordingly for ease of identification during data collection. All the data from a particular replicate were also grouped and also labelled as data from a given particular replicate. The fresh weight of all the 'tagged plants' was determined and the tagged plants subsequently dried until moisture level was around 12.5-13%.

3.4.3 Dry matter biomass and root Length

The final data collected was on the below and above ground biomass. The above ground biomass was carried out by complete removal of the harvested maize plant. Cutting was made from the topmost part of the maize plant to the point of root formation or the last node of the maize plant which is in complete contact with soil surface (Maize stalk). Below ground biomas was considered as the biomass of the maize plant which was inside the soil (plant root). The root which was detached from the main plant was thoroughly washed and dried. The fresh and dried weight was recorded and subsequently the total root length was also measured. This was repeated for all the tagged plants under study.

3.5 Statistical Analysis

Data collected from all the treatments measured was analyzed using Statistix 8.0 analytical software. The results for all the treatments were analyzed statistically using Analysis of Variance (ANOVA). Significance level at 5% was used for all the analyses and mean separation based on Least Significance Difference (LSD) was calculated where significance difference was found among treatments means.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and provides the relevant interpretation for discussion.

4.2. Growth parameters of *Akpose* Maize

The effect of organic and inorganic fertilizer and their combined effect on the growth parameters of maize are discussed in this chapter.

4.2.1: Mean Number of leaves

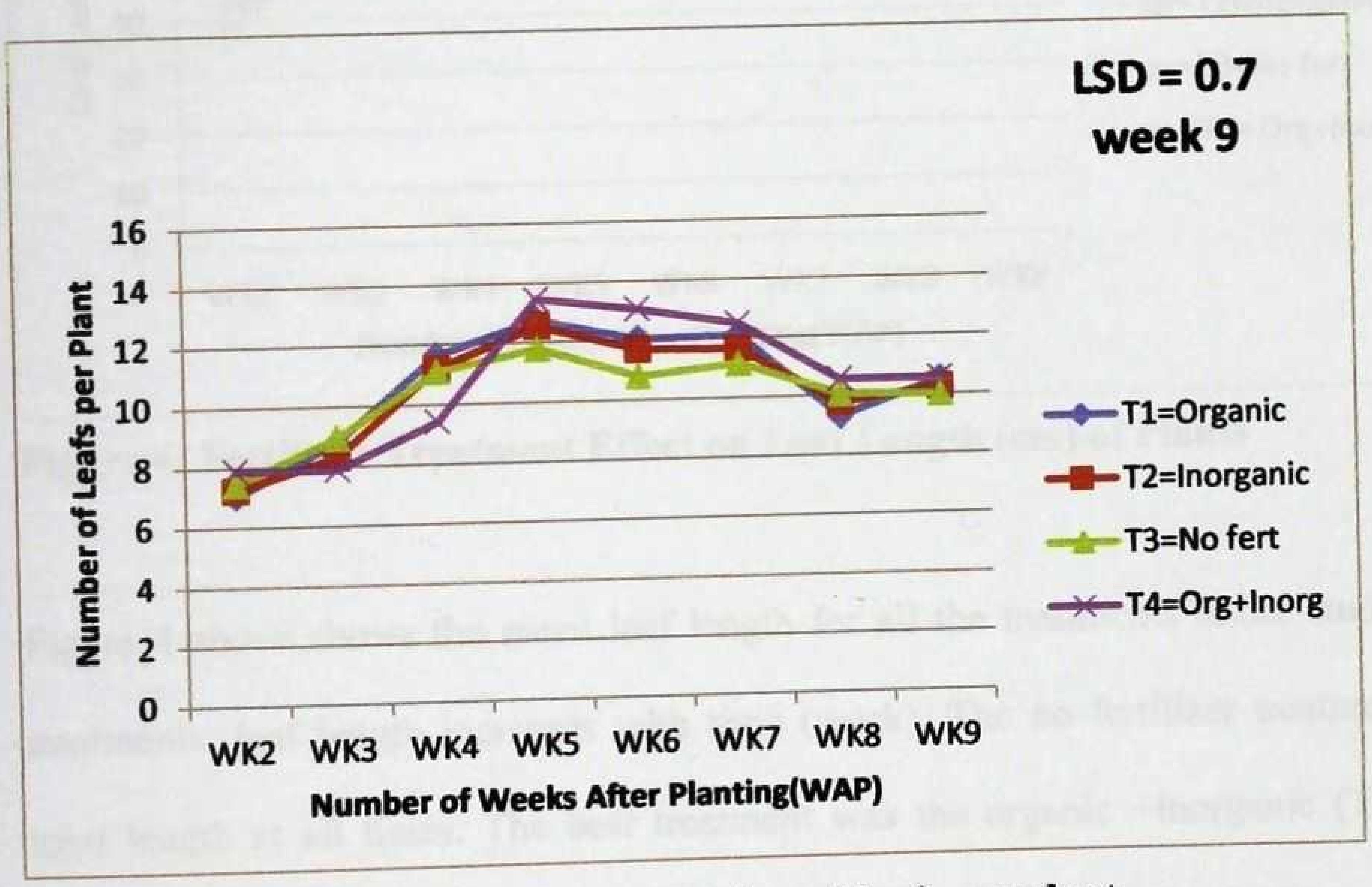

Figure 3: Effect of Treatments on Number of leafs per plant

Figure 2, shows the mean number of leafs observed from 2[nd] to the 9[th] week after planting for the four treatments under study. All the treatments in the second week after planting had similar plant height, except for (T4) which was slightly above slightly above the rest of the treatments. The highest number of leaves was obtained at week 6 for all treatments. There was no significance difference among treatment of number of leaves at any of the weeks.

4.2.2 Leaf Length (cm)

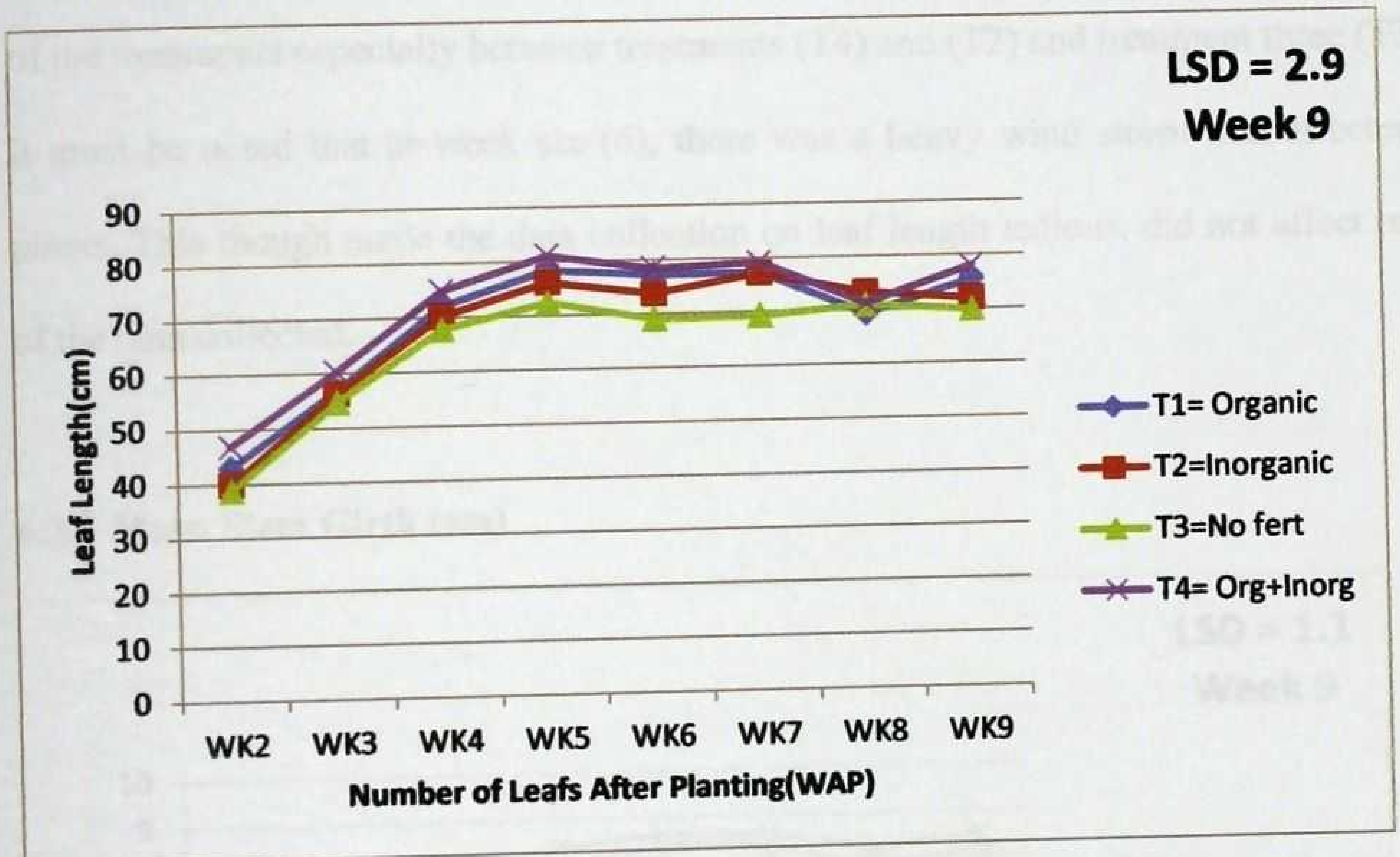

Figure 4: Fertilizer Treatment Effect on Leaf Length (cm) of Plants

Figure 4 above shows the mean leaf length for all the treatments under study. For all treatments, leaf length increases with time (week). The no fertilizer treatment had the least length at all times. The best treatment was the organic +inorganic (T_4) showing highest leaf length for all the weeks. Significant difference ($P< 0.05$) was recorded between T1 and T4 and the rest of the treatments (T3, T2). T4 recorded the highest leaf length of 77.9cm at the end of the ninth week which was significantly higher than that of T2and T3 but not significantly different from T1 which recorded mean leaf length of 75.4cm. Highest and significant difference ($P< 0.05$) was achieved at week five (5) between treatments four (T4) and the rest of the treatments. Treatment four (T4) had the highest mean leaf length of 81.1cm, followed by Treatment one (T1) with 78.4cm, treatment two (T2) and finally with treatment (T3) recording the lowest mean leaf length of 72.385cm. At week eight (WK8), significant difference did not exist among all the treatments. At week nine (WK9), there was significant difference ($P < 0.05$) among some of the treatments especially between treatments (T4) and (T2) and treatment three (T3). It must be noted that at week six (6), there was a heavy wind storm that affected the plants. This though made the data collection on leaf length tedious, did not affect results of the data collected.

4.2.3 Mean Stem Girth (cm)

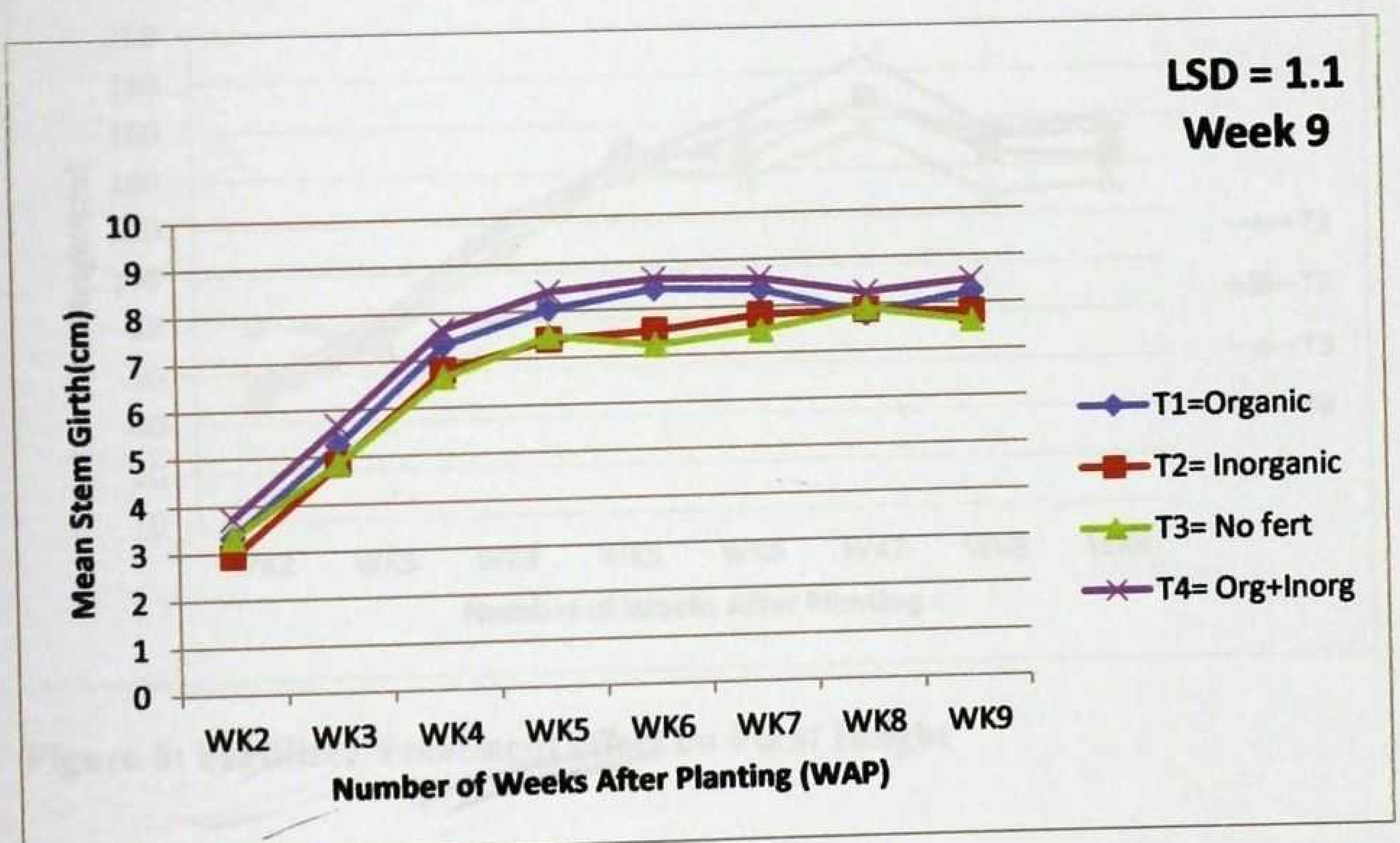

Figure 5: Fertilizer treatment effect on Mean Stem Girth

From figure 5 it can be deduced that, there was a general increase in stem girth as the number of week's increases. Significant difference (P< 0.05) existed among some of the treatments at week two (2), for instance between treatments four T4 and T3. There was a marginally increase in stem girth as the weeks increases until the nine (9^{th}) week where there was no significant difference among all the treatments. At the end of the ninth week, organic +Inorganic treatment (T4) recorded the highest mean stem girth (8.5cm), followed by T1 (8.2cm), T2 (7.8cm) and T3 (7.6cm) (i.eT4>T2>T3>T1.)

4.2.4: Mean Plant Height (cm)

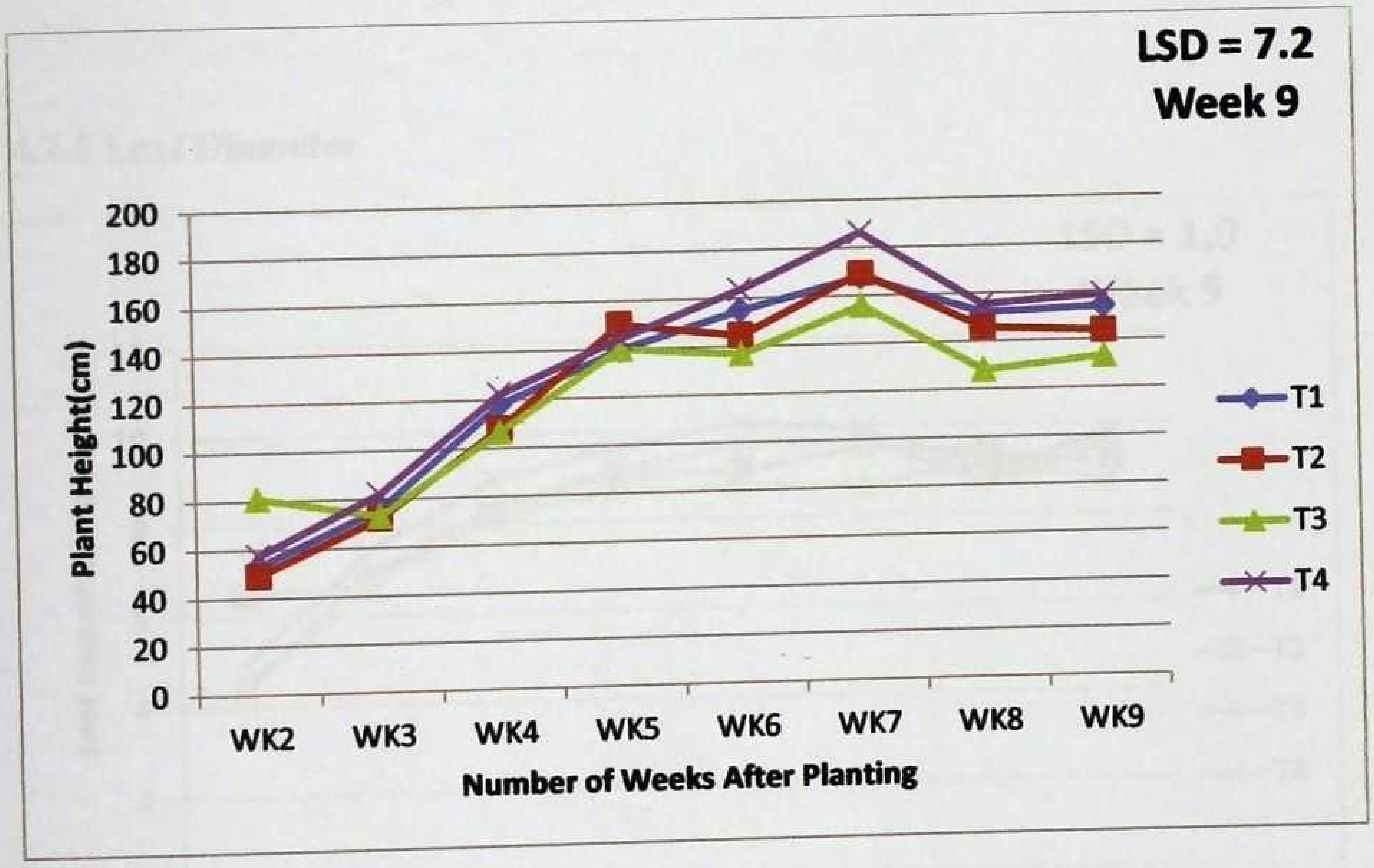

Figure 6: Fertilizer Treatment effect on Plant Height

Figure 6 above shows the mean plant height for the various treatments under study from week two to week nine. Generally, plant height increased as the number of week's progresses. Also the result shows that there was a significant difference (P<0.05) in increase in plant height as far as treatment four T4 was concern, followed by treatment one T1, T2 with T3recording the least value of 133.1cm.

Both treatment one (T1) and treatment two (T4) recorded mean values of 153.8cm and 158.0 respectively which were not significantly different (P>0.05) from each other. This could be attributed to the adequate supply of nutrients by both treatments which led to a significant increase in plant height compared to the rest of the treatments. The low plant height values recorded by treatment (T2) could be due to leaching of readily available nutrients since there was continuous rain at the time of the project implementation.

4.2.5 Leaf Diameter

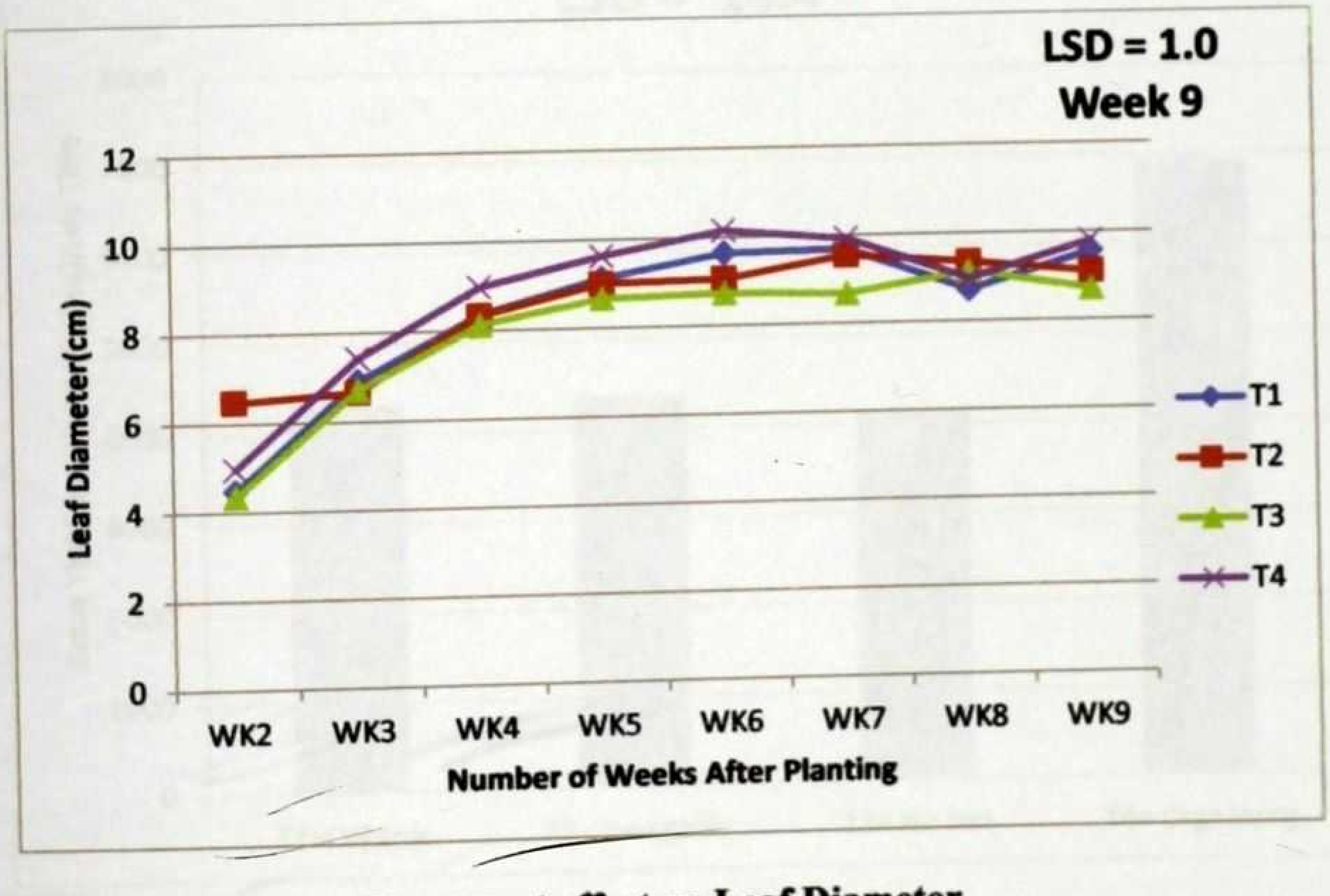

Figure 7: Fertilizer Treatment effect on Leaf Diameter

Results from the analysis of leaf diameter showed no significance difference among all the treatments at the end of the ninth week. Though, T4 recorded the highest mean value of 6.5cm, this was not significantly different (P<0.05) from the rest of the treatment. The lowest mean leaf diameter was recorded by treatment three. Generally, on the field, it was observed that the leaves of T1 were very green in colour compared with the other treatments. This is an indication that T1 received enough Nitrogen from the fertilizer applied

4.3 Yield Parameters of *Akposoe* Maize

4.3.1: Mass of Grain (Yield) at 13% Moisture Content

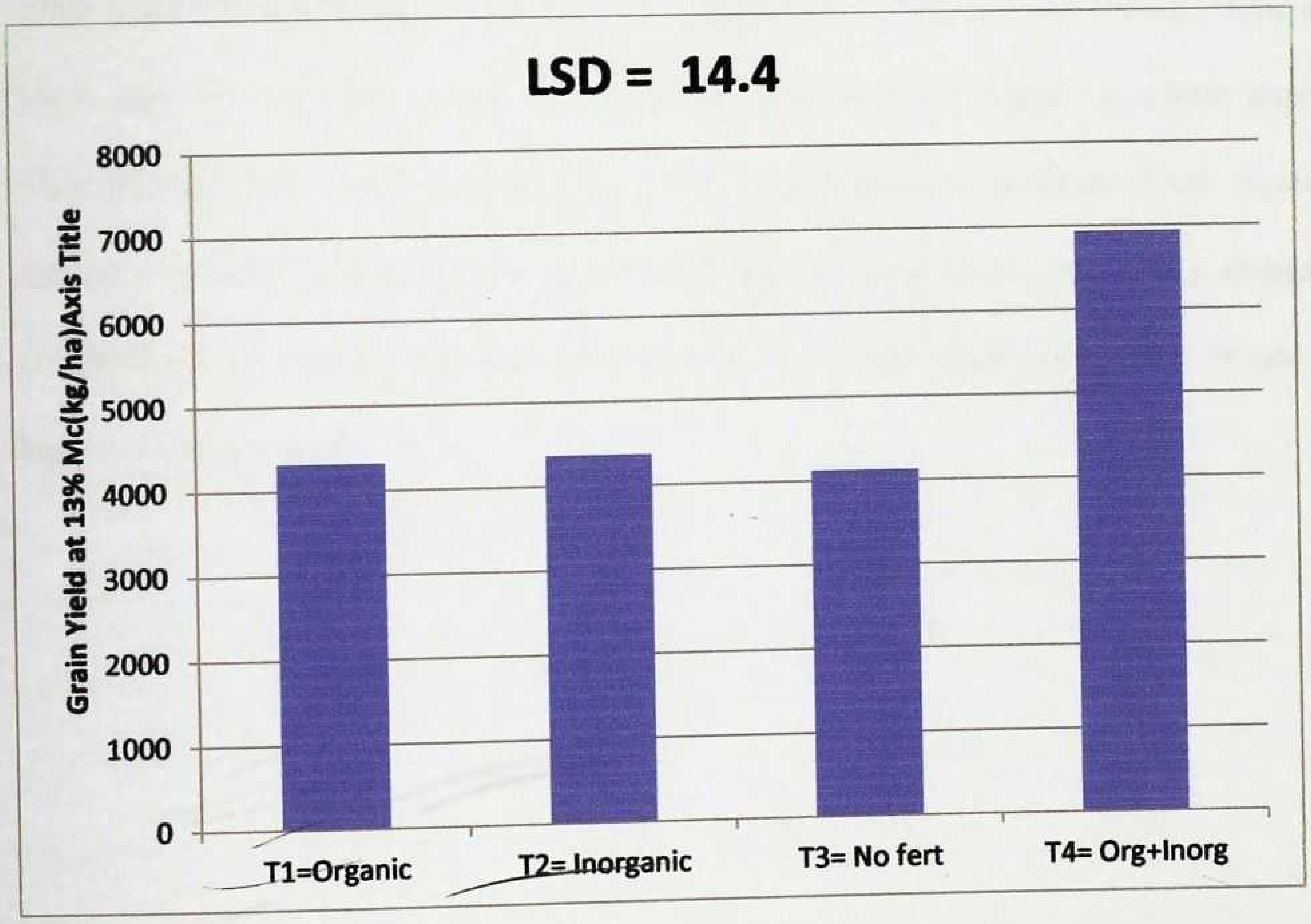

Figure 8: Mass of Grain (kg/ha) at 13% Moisture Content

Results from the analysis of grain yield showed significance difference ($P<0.05$) between T4 and the rest of the treatments. In all T4 had the highest mean seed weight of 6937.6kg/ha. This was followed by T1and T2 having mean values of 4322kg/h and 4366kg/ha respectively. The least seed weight was recorded by T3 with mean seed weight of 4124.3kg/ha. The yield recorded by T4 could be as a result of the combined effect of the organic and inorganic fertilizer. The inorganic fertilizer provided readily available nutrients to the maize plants whereas the organic fertilizer though very slow in nutrient release might have improved the condition of the soil thereby allowing the nutrient released from the inorganic fertilizer stay longer in the soil for the plant to make good use of. This subsequently led to the improvement in the grain yield of the maize plant under the application of T4 (Organic+ inorganic fertilizer).This results confirms the work done by Asumadu *et al*.,(2012), which states that the organic fertilizer improved yield slightly only when in combination with inorganic NPK fertilizer. From figure 8 it can be concluded that for proper growth and high yield of maize under drip fertigation, combination of organic and inorganic fertilizers in their right proportion would give higher yield of maize.

4.3. 2 Above Ground Biomass (kg/ha)

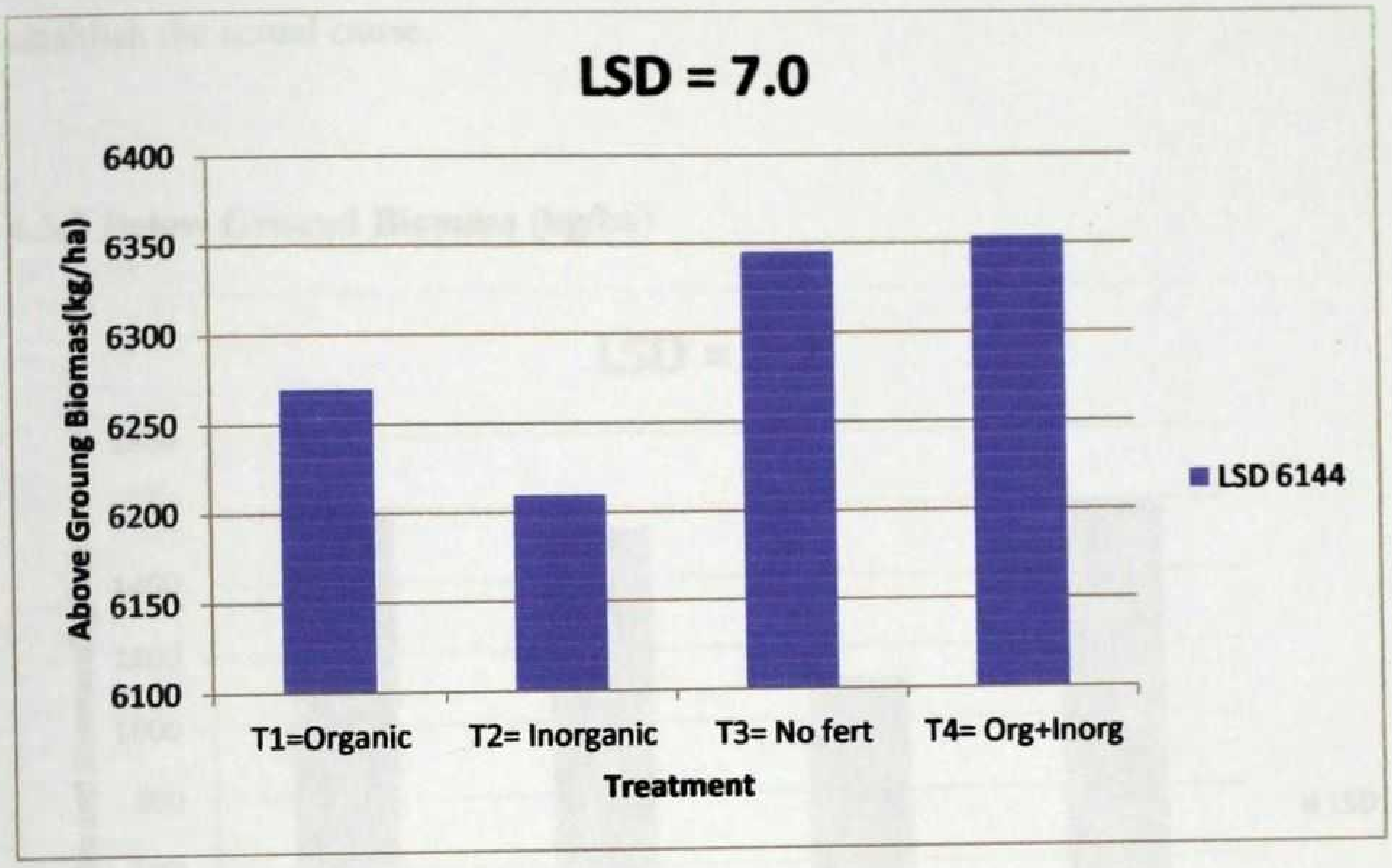

Figure 9: Fertilizer effect above Ground Biomass (kg/ha)

Figure 7 illustrates the effect of the various treatments on the above ground biomass of the *Akposoe* maize variety. Generally, significance difference was not achieved among all the treatments when subjected to analysis of variance at 5% confidence level. Though, treatment four recorded the highest mean value of above ground biomas of 6353.6kg/ha, it was not significantly different from the rest of the treatments. Treatment four was followed by T3 having 6345.6kg/ha, followed by T1 which also had 6269.6kg/ha. Surprisingly, T2 (Inorganic treatment) had the least value of 6209.6kg/ha. The reason for T3 having comparatively higher above ground biomas could be as a result of lack of nutrient. Therefore the T3 had to go through stress to be able to get enough nutrients, hence the vegetative growth in T3. Other environmental factors such as high temperature and wind could have also contributed to that. This is because high temperature and steady prevailing wind could lead to high evapotranspiration rate. but the study could not establish the actual cause.

4.3.3 Below Ground Biomass (kg/ha)

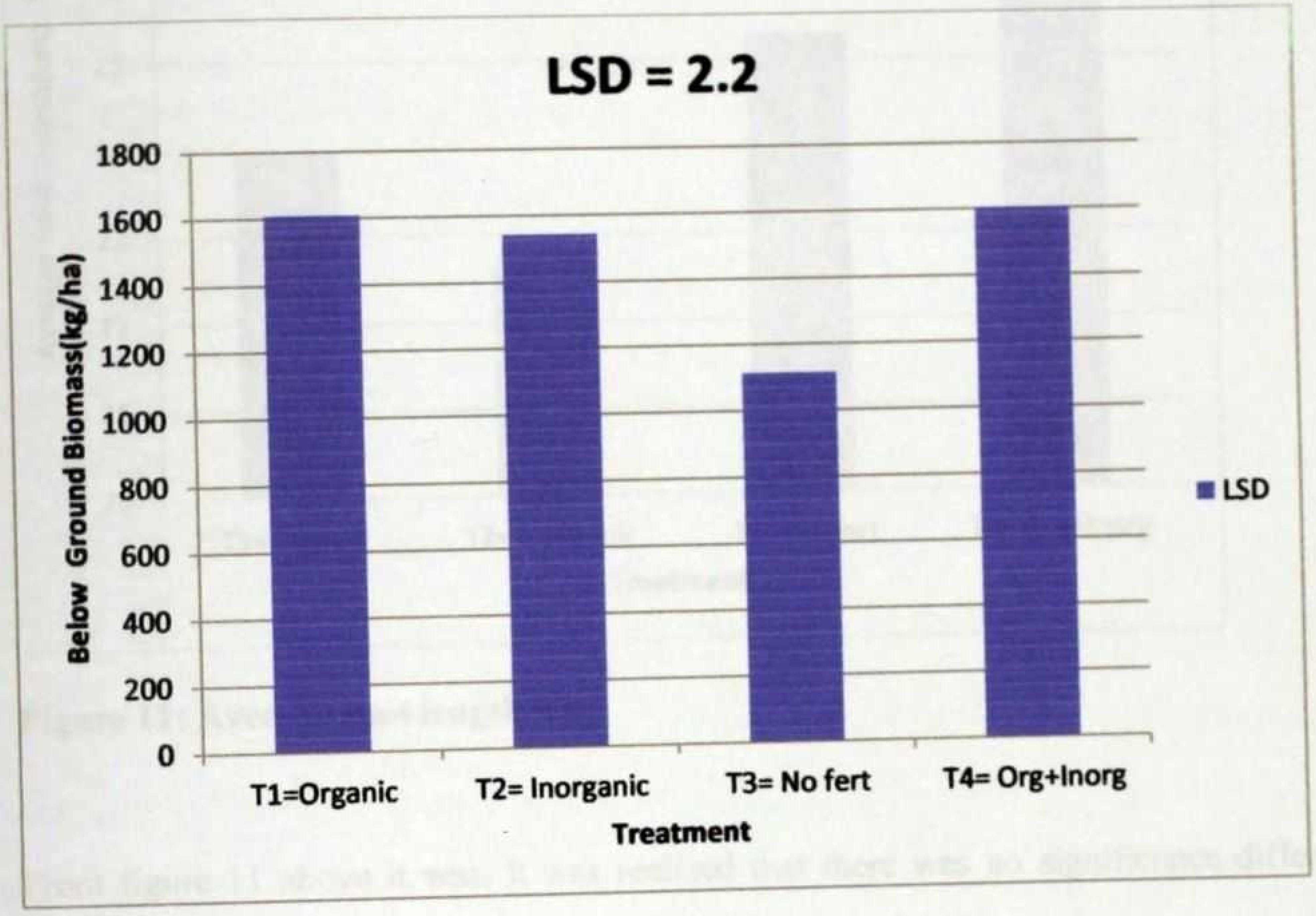

Figure 10: Fertilizer effect on Below Ground Biomass (kg/ha)

Results from the analysis of below ground biomass are presented in figure 10. From the analysis it was deduced that there was significant difference ($P<0.05$) between T3 and the rest of the treatment.T3 had the least value of 1113.6kg/ha with the rest of the treatments performing better in terms of below ground biomass with values ranging from 1608.2kg/ha,1542.4kg/ha and1604kg/ha for T1, T2 and T4respectively. From the results it is clear that all the treatments supplied enough nutrients which the plants utilized to generate enough below ground biomass.

4.3.4 Average Root Length (cm)

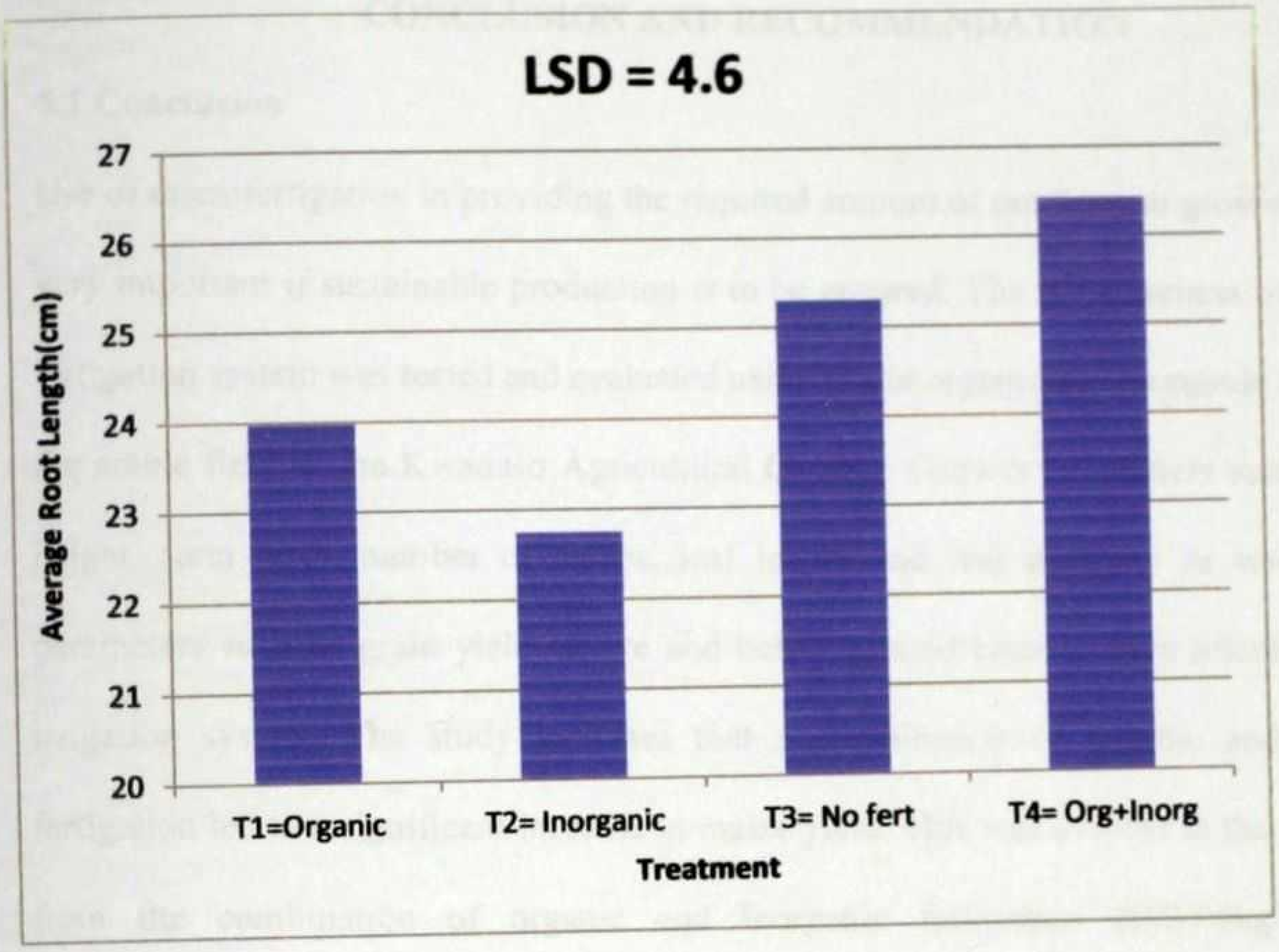

Figure 11: Average root length (cm)

From figure 11 above it was, it was realized that there was no significance difference among all the treatments under study. All the treatments produced root lengths that were not significantly different from each other. In all, T_4 produced the highest root length of 26.4cm followed by T3 (25.3cm), T1 (24.0cm) and T2 (22.7cm) all in the order of T4>T3>T1>T2.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Use of microfertigation in providing the required amount of nutrients to growing plants is very important if sustainable production is to be ensured. The effectiveness of PVC drip fertigation system was tested and evaluated using liquid organic and inorganic fertilizer at the arable field of the Kwadaso Agricultural College. Growth parameters such as: Plant height, stem girth, number of leaves, leaf length and leaf diameter as well as yield parameters such as grain yield, above and below ground biomas were affected by drip irrigation system. The study indicates that a combination of organic and inorganic fertigation led to a significant increase in maize yield. This was evident in the grain yield from the combination of organic and inorganic fertigation (6937.6kg/ha) being significantly ($P<0.05$) higher than the inorganic fertilizer treatment (4366 kg/ha), organic fertilizer treatment (4322kg/ha) and no fertilizer treatment (4124.3kg/ha).

5.2 Recommendations

At the end of the research study, the following recommendations were drawn;

- The research study should be repeated to confirm the results and establish how maize responds to drip fertigation.

- On farm trials, should be carried out using simple PVC drip fertigation system to enable farmers adopt and practice the technology effectively to increase their productivity.

- The system could be used by used by Research Institutions, Agricultural College, and Farm Institute in training students.

- Also further studies should be carried out to compare liquid with the solid for both organic and inorganic fertilizers.

- Further research should carried out into varying the amount of fertilizer applied compared with the recommended rates.

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APPENDICES

APPENDICES A- GROWTH PARAMETERS OF AKPOSOE MAIZE

TABLE 1: Results of Number of leaves per Plant

TREATMENTS	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
T1(Organic)	7.050A	8.800A	11.650AB	12.750AB	12.050B	12.100AB	9.300B	10.500A
T2(Inorganic)	7.250A	8.300A	11.200B	12.550AB	11.700B	11.650AB	9.750AB	10.250A
T3(No fert)	7.450A	8.950A	11.100B	11.800B	10.800C	11.150B	10.050A	10.000A
T4(org+Inorg)	7.900A	7.900A	9.4250A	13.450A	13.050A	12.500A	10.550A	10.550A
G. Mean	7.4125	7.412	9.425	12.638	11.900	11.850	9.6750	10.50
LSD								
CV	7.82	7.82	5.57	6.05	4.04	7.11	3.18	7.68

TABLE 2: Results of Leaf Length per Plant(cm)

TREATMENTS	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
T1(Organic)	42.975 AB	56.905A	72.135A	78.400AB	77.225A	77.345A	69.360A	75.365A
T2(Inorganic)	39.865 B	56.345A	70.185A	76.125BC	73.755AB	77.185A	73.280A	71.940B
T3(No fert)	38.810 B	54.735A	67.840A	72.385C	69.025B	69.330B	70.995A	69.860B
T4(Org+Inorg)	46.910 A	60.361A	74.870A	81.065A	78.395A	79.100A	71.280A	77.940A
G. Mean	42.140	57.087	71.258	76.994	74.600	75.740	71.229	73.776
LSD								
CV	7.68	7.11	CV 6.60	3.80	4.14	2.63	6.26	2.45

Table 3: Results of Mean Stem Girth (cm)

Treatment	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
T1(Organic)	3.3450 AB	5.2650 A	7.3250 A	8.0400AB	8.4250AB	8.3650 AB	7.8000A	8.2250A
T2(Inorganic)	2.9450B	4.8650 A	6.7950 A	7.3950 B	7.5400BC	7.8200AB	7.8800A	7.8000A
T3(No fert)	3.3450AB	4.8800A	6.6550A	7.4650AB	7.2400C	7.4950 B	7.9100A	7.6100A
T4(Org+Inor)	3.7400 A	5.6713 A	7.6600 A	8.4050 A	8.6400 A	8.6000 A	8.2500A	8.4950A
G. Mean	3.2425	5.1703	7.1088	7.8263	7.9613	8.0700	7.9600	8.0325
LSD								
CV	10.89	11.21	10.17	7.97	7.60	7.20	5.31	8.44

Table 4: Results of Plant Height (cm)

TREATMENTS	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
T1(Organic)	53.260A	75.940B	117.87B	139.5A	154.9A	167.8A	151.92B	153.8A
T2(Inorganic)	49.295A	72.090 B	108.18 B	150.1A	144.5A	169.3A	145.70 B	143.7B
T3(No fert)	80.980A	73.170 B	106.69 B	139.8A	136.7A	155.8A	127.99 C	133.1C
T4(Org+Inorg)	57.500A	82.201 A	122.37 A	144.2A	163.5A	186.3A	155.29 A	158.8A
G. Mean	60.259	75.850	113.78	143.47	149.92	194.85	145.23	147.40
LSD								
CV	48.47	5.79	7.72	5.97	11.28	45.06	3.81	3.04

Table 5: Leaf Diameter(cm)

WEEKS	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
T1	4.4800A	6.9100A	8.3600A	9.1250AB	9.635AB	**9.6850A**	8.710A	9.5550 A
T2	6.4750A	6.6600A	8.3400A	9.0050AB	9.055 BC	9.5400A	9.340A	9.1000 AB
T3	4.3500A	6.7100A	8.1300A	8.6700 B	8.735 C	8.6750B	9.135A	8.7050 B
T4	4.9650A	7.4238A	8.9750A	9.6250 A	10.145 A	9.9200A	8.965A	9.7900 A
G.Mean	5.0675	6.9259	8.4513	9.1062	9.3925	9.4550	9.0375	9.2875
LSD								
CV	39.47	9.21	8.4513	5.84	5.46	4.30	7.11	5.54

APPENDIX B- ANOVA VALUES FOR GROWTH PARAMETERS

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Randomized Complete Block AOV Table for Number of leaves (NL2)

Source	DF	SS	MS	F	P
Block	3	1.74750	0.58250		
Treatment	3	1.58750	0.52917	1.58	0.2621
Error	9	3.02250	0.33583		
Total	15	6.35750			

Grand Mean 7.4125 CV 7.82

LSD All-Pairwise Comparisons Test of Number of leaves (NL2) for Treatment

Treatment Mean		Homogeneous Groups
T4	7.9000	A
T3	7.4500	A
T2	7.2500	A
T1	7.0500	A

Alpha 0.05

Critical Value for Comparison 0.9270

Randomized Complete Block AOV Table for Number of leaves (NL3)

Source	DF	SS	MS	F	P
Block	3	6.8269	2.27562		
Treatment	3	2.5769	0.85896	1.59	0.2581
Error	9	4.8506	0.53896		
Total	15	14.2544			

Grand Mean 8.8688 CV 8.28

LSD All-Pairwise Comparisons Test of Number of leaves (NL3) for Treatment

Treatment	Mean	Homogeneous Groups
T4	9.4250	A
T3	8.9500	A
T1	8.8000	A
T2	8.3000	A

Alpha 0.05

Critical Value for Comparison 1.1743

Randomized Complete Block AOV Table for NL4

Source	DF	SS	MS	F	P
Block	3	8.3800	2.79333		
Treatment	3	3.3000	1.10000	2.66	0.1115
Error	9	3.7200	0.41333		
Total	15	15.4000			

Grand Mean 9.4250 A CV 5.57

LSD All-Pairwise Comparisons Test of Number of Leaves (NL4) for Treatment

Treatment	Mean	Homogeneous Groups
T4	12.250	A
T1	11.650	AB
T2	11.200	B
T3	11.100	B

Alpha 0.05
Critical Value for Comparison 1.0284

Randomized Complete Block AOV Table for Number of Leaves (NL5)

Source	DF	SS	MS	F	P
Block	3	5.0675	1.68917		
Treatment	3	5.5275	1.84250	3.15	0.0791
Error	9	5.2625	0.58472		
Total	15	15.8575			

Grand Mean 12.638 CV 6.05

LSD All-Pairwise Comparisons Test of Number of Leaves (NL5) for Treatment

Treatment	Mean	Homogeneous Groups
T4	13.450	A
T1	12.750	AB
T2	12.550	AB
T3	11.800	B

Alpha 0.05
Critical Value for Comparison 1.2232

Randomized Complete Block AOV Table for Number of Leaves (NL6)

Source	DF	SS	MS	F	P
Block	3	3.8600	1.28667		
Treatment	3	10.3800	3.46000	14.97	0.0008
Error	9	2.0800	0.23111		
Total	15	16.3200			

Grand Mean 11.900 CV 4.04

LSD All-Pairwise Comparisons Test of Number of Leaves (NL6) for Treatment

Treatment	Mean	Homogeneous Groups
T4	13.050	A
T1	12.050	B
T2	11.700	B
T3	10.800	C

Alpha 0.05
Critical Value for Comparison 0.7690

Randomized Complete Block AOV Table for Number of Leaves (NL7)

Source	DF	SS	MS	F	P
Block	3	2.1600	0.72000		
Treatment	3	4.0600	1.35333	1.91	0.1986
Error	9	6.3800	0.70889		
Total	15	12.6000			

Grand Mean 11.850 CV 7.11

LSD All-Pairwise Comparisons Test of Number of Leaves (NL7) for Treatment

Treatment	Mean	Homogeneous Groups
T4	12.500	A
T1	12.100	AB
T2	11.650	AB
T3	11.150	B

Alpha 0.05
Critical Value for Comparison 1.3468

Randomized Complete Block AOV Table for Number of Leaves (NL8)

Source	DF	SS	MS	F	P
Block	3	1.25000	0.41667		
Treatment	3	1.17000	0.39000	4.13	0.0426
Error	9	0.85000	0.09444		
Total	15	3.27000			

Grand Mean 9.6750 CV 3.18

LSD All-Pairwise Comparisons Test of Number of Leaves (NL8) for Treatment

Treatment	Mean	Homogeneous Groups
T3	10.050	A
T2	9.750	AB
T4	9.600	AB
T1	9.300	B

Alpha 0.05
Critical Value for Comparison 0.4916

Randomized Complete Block AOV Table for Number of Leaves (NL9)

Source	DF	SS	MS	F	P
Block	3	1.89000	0.63000		
Treatment	3	0.77000	0.25667	1.28	0.3401
Error	9	1.81000	0.20111		
Total	15	4.47000			

Grand Mean 10.325 CV 4.34

LSD All-Pairwise Comparisons Test of Number of Leaves (NL9) for Treatment

Treatment	Mean	Homogeneous Groups
T4	10.550	A
T1	10.500	A
T2	10.250	A
T3	10.000	A

Alpha 0.05
Critical Value for Comparison 0.7173

Randomized Complete Block AOV Table for Leaf Length(LL2)

Source	DF	SS	MS	F	P
Block	3	259.858	86.6193		
Treatment	3	158.859	52.9529	5.06	0.0252
Error	9	94.186	10.4651		
Total	15	512.902			

Grand Mean 42.140 CV 7.68

LSD All-Pairwise Comparisons Test of Leaf Length (LL2) for Treatment

Treatment	Mean	Homogeneous Groups
T4	46.910	A
T1	42.975	AB
T2	39.865	B
T3	38.810	B

Alpha 0.05
Critical Value for Comparison 5.1746

Randomized Complete Block AOV Table for Leaf Length(LL3)

Source	DF	SS	MS	F	P
Block	3	532.399	177.466		
Treatment	3	67.345	22.448	1.36	0.3151
Error	9	148.250	16.472		
Total	15	747.994			

Grand Mean 57.087 CV 7.11

LSD All-Pairwise Comparisons Test of Leaf Length (LL3) for Treatment

Treatment	Mean	Homogeneous Groups
T4	60.361	A
T1	56.905	A
T2	56.345	A
T3	54.735	A

Alpha 0.05
Critical Value for Comparison 6.4921

Randomized Complete Block AOV Table for Leaf Length (LL4)

Source	DF	SS	MS	F	P
Block	3	348.748	116.249		
Treatment	3	106.599	35.533	1.61	0.2550
Error	9	198.850	22.094		
Total	15	654.197			

Grand Mean 71.258 CV 6.60

LSD All-Pairwise Comparisons Test of Leaf Length (LL4) for Treatment

Treatment	Mean	Homogeneous Groups
T4	74.870	A
T1	72.135	A
T2	70.185	A
T3	67.840	A

Alpha 0.05
Critical Value for Comparison 7.5188

Randomized Complete Block AOV Table for Leaf Length (LL5)

Source	DF	SS	MS	F	P
Block	3	28.862	9.6208		
Treatment	3	162.192	54.0639	6.33	0.0134
Error	9	76.854	8.5394		
Total	15	267.909			

Grand Mean 76.994 CV 3.80

LSD All-Pairwise Comparisons Test for Leaf Length (LL5) for Treatment

Treatment	Mean	Homogeneous Groups
T4	81.065	A
T1	78.400	AB
T2	76.125	BC
T3	72.385	C

Alpha 0.05
Critical Value for Comparison 4.6743

Randomized Complete Block AOV Table for Leaf Length (LL6)

Source	DF	SS	MS	F	P
Block	3	23.763	7.9209		
Treatment	3	212.349	70.7831	7.43	0.0083
Error	9	85.726	9.5251		
Total	15	321.838			

Grand Mean 74.600 CV 4.14

LSD All-Pairwise Comparisons Test of Leaf Length (LL6) for Treatment

Treatment	Mean	Homogeneous Groups
T4	78.395	A
T1	77.225	A
T2	73.755	AB
T3	69.025	B

Alpha 0.05
Critical Value for Comparison 4.9368

Randomized Complete Block AOV Table for Leaf Length(LL7)

Source	DF	SS	MS	F	P
Block	3	69.767	23.2558		
Treatment	3	228.167	76.0557	19.19	0.0003
Error	9	35.666	3.9629		
Total	15	333.601			

Grand Mean 75.740 CV 2.63

LSD All-Pairwise Comparisons Test of Leaf Length(LL7) for Treatment

Treatment	Mean	Homogeneous Groups
T4	79.100	A
T1	77.345	A
T2	77.185	A
T3	69.330	B

Alpha 0.05
Critical Value for Comparison 3.1843

Randomized Complete Block AOV Table for Leaf Length(LL8)

Source	DF	SS	MS	F	P
Block	3	111.020	37.0068		
Treatment	3	31.028	10.3428	0.52	0.6787
Error	9	178.847	19.8719		
Total	15	320.896			

Grand Mean 71.229 CV 6.26

LSD All-Pairwise Comparisons Test of Leaf Length(LL8) for Treatment

Treatment	Mean	Homogeneous Groups
T2	73.280	A
T4	71.280	A
T3	70.995	A
T1	69.360	A

Alpha 0.05
Critical Value for Comparison 7.1306

Randomized Complete Block AOV Table for Leaf Length(LL9)

Source	DF	SS	MS	F	P
Block	3	18.613	6.2045		
Treatment	3	154.279	51.4264	15.70	0.0006
Error	9	29.484	3.2760		
Total	15	202.376			

Grand Mean 73.776 CV 2.45

LSD All-Pairwise Comparisons Test of Leaf Length(LL9) for Treatment

Treatment	Mean	Homogeneous Groups
T4	77.940	A
T1	75.365	A
T2	71.940	B
T3	69.860	B

Alpha 0.05
Critical Value for Comparison 2.8952

Randomized Complete Block AOV Table for (Stem Girth(SG2)

Source	DF	SS	MS	F	P
Block	3	3.29130	1.09710		
Treatment	3	1.75210	0.58403	4.69	0.0309
Error	9	1.12130	0.12459		
Total	15	6.16470			

Grand Mean 3.2425 CV 10.89

LSD All-Pairwise Comparisons Test of Stem Girth(SG2) for Treatment

Treatment	Mean	Homogeneous Groups
T4	3.7400	A
T1	3.3450	AB
T3	2.9450	B
T2	2.9400	B

Alpha 0.05
Critical Value for Comparison 0.5646

Randomized Complete Block AOV Table for Stem Girth(SG3)

Source	DF	SS	MS	F	P
Block	3	11.8001	3.93337		
Treatment	3	1.7496	0.58320	1.74	0.2288
Error	9	3.0214	0.33571		
Total	15	16.5711			

Grand Mean 5.1703 CV 11.21

LSD All-Pairwise Comparisons Test of Stem Girth(SG3) for Treatment

Treatment	Mean	Homogeneous Groups
T4	5.6713	A
T1	5.2650	A
T3	4.8800	A
T2	4.8650	A

Alpha 0.05
Critical Value for Comparison 0.9268

Randomized Complete Block AOV Table for Stem Girth(SG4)

Source	DF	SS	MS	F	P
Block	3	18.7593	6.25309		
Treatment	3	2.6199	0.87329	1.67	0.2421
Error	9	4.7080	0.52311		
Total	15	26.0872			

Grand Mean 7.1088 CV 10.17

LSD All-Pairwise Comparisons Test of Stem Girth(SG4) for Treatment

Treatment	Mean	Homogeneous Groups
T4	7.6600	A
T1	7.3250	A
T2	6.7950	A
T3	6.6550	A

Alpha 0.05
Critical Value for Comparison 1.1569

Randomized Complete Block AOV Table for Stem Girth(SG5)

Source	DF	SS	MS	F	P
Block	3	3.9499	1.31663		
Treatment	3	2.7885	0.92949	2.39	0.1364
Error	9	3.5022	0.38914		
Total	15	10.2406			

Grand Mean 7.8263 CV 7.97

LSD All-Pairwise Comparisons Test of Stem Girth(SG5) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.4050	A
T1	8.0400	AB
T3	7.4650	AB
T2	7.3950	B

Alpha 0.05
Critical Value for Comparison 0.9978

Randomized Complete Block AOV Table for Stem Girth(SG6)

Source	DF	SS	MS	F	P
Block	3	2.6595	0.88649		
Treatment	3	5.4937	1.83122	5.00	0.0261
Error	9	3.2960	0.36622		
Total	15	11.4492			

Grand Mean 7.9613 CV 7.60

LSD All-Pairwise Comparisons Test of Stem Girth(SG6) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.6400	A
T1	8.4250	AB
T2	7.5400	BC
T3	7.2400	C

Alpha 0.05
Critical Value for Comparison 0.9680

Randomized Complete Block AOV Table for Stem Girth(SG7)

Source	DF	SS	MS	F	P
Block	3	7.1864	2.39547		
Treatment	3	3.0442	1.01473	3.01	0.0872
Error	9	3.0350	0.33722		
Total	15	13.2656			

Grand Mean 8.0700 CV 7.20

LSD All-Pairwise Comparisons Test of Stem Girth(SG7) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.6000	A
T1	8.3650	AB
T2	7.8200	AB
T3	7.4950	B

Alpha 0.05
Critical Value for Comparison 0.9289

Randomized Complete Block AOV Table for Stem Girth(SG8)

Source	DF	SS	MS	F	P
Block	3	4.49660	1.49887		
Treatment	3	0.47440	0.15813	0.89	0.4841
Error	9	1.60500	0.17833		
Total	15	6.57600			

Grand Mean 7.9600 CV 5.31

LSD All-Pairwise Comparisons Test of Stem Girth(SG8) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.2500	A
T3	7.9100	A
T2	7.8800	A
T1	7.8000	A

Alpha 0.05
Critical Value for Comparison 0.6755

Randomized Complete Block AOV Table for Stem Girth(SG9)

Source	DF	SS	MS	F	P
Block	3	3.12090	1.04030		
Treatment	3	1.93410	0.64470	1.40	0.3041
Error	9	4.13370	0.45930		
Total	15	9.18870			

Grand Mean 8.0325 CV 8.44

LSD All-Pairwise Comparisons Test of Stem Girth(SG9) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.4950	A
T1	8.2250	A
T2	7.8000	A
T3	7.6100	A

Alpha 0.05
Critical Value for Comparison 1.0841

Randomized Complete Block AOV Table for Plant Height(PH2)

Source	DF	SS	MS	F	P
Block	3	2834.2	944.726		
Treatment	3	2424.7	808.223	0.95	0.4578
Error	9	7678.0	853.113		
Total	15	12936.9			

Grand Mean 60.259 CV 48.47

LSD All-Pairwise Comparisons Test of Plant Height(PH2) for Treatment

Treatment	Mean	Homogeneous Groups
T3	80.980	A
T4	57.500	A
T1	53.260	A
T2	49.295	A

Alpha 0.05
Critical Value for Comparison 46.721

Randomized Complete Block AOV Table for Plant Height(PH3)

Source	DF	SS	MS	F	P
Block	3	1386.11	462.036		
Treatment	3	246.67	82.222	4.26	0.0394
Error	9	173.67	19.297		
Total	15	1806.45			

Grand Mean 75.850 CV 5.79

LSD All-Pairwise Comparisons Test of Plant Height(PH3) for Treatment

Treatment	Mean	Homogeneous Groups
T4	82.201	A
T1	75.940	AB
T3	73.170	B
T2	72.090	B

Alpha 0.05
Critical Value for Comparison 7.0267

Randomized Complete Block AOV Table for Plant Height(PH4)

Source	DF	SS	MS	F	P
Block	3	2496.21	832.071		
Treatment	3	688.86	229.620	2.97	0.0893
Error	9	694.82	77.202		
Total	15	3879.89			

Grand Mean 113.78 CV 7.72

LSD All-Pairwise Comparisons Test of (Plant Height(PH4) for Treatment

Treatment	Mean	Homogeneous Groups
T4	122.37	A
T1	117.87	AB
T2	108.18	B
T3	106.69	B

Alpha 0.05
Critical Value for Comparison 14.055

Randomized Complete Block AOV Table for Plant Height(PH5)

Source	DF	SS	MS	F	P
Block	3	4069.39	1356.46		
Treatment	3	1652.71	550.90	1.93	0.1957
Error	9	2571.92	285.77		
Total	15	8294.02			

Grand Mean 149.92 CV 11.28

LSD All-Pairwise Comparisons Test of Plant Height(PH5) for Treatment

Treatment	Mean	Homogeneous Groups
T4	163.54	A
T1	154.90	A
T2	144.52	A
T3	136.74	A

Alpha 0.05
Critical Value for Comparison 27.041

Randomized Complete Block AOV Table for Plant Height(PH6)

Source	DF	SS	MS	F	P
Block	3	24369	8123.1		
Treatment	3	30250	10083.4	1.31	0.3307
Error	9	69383	7709.2		
Total	15	124002			

Grand Mean 194.85 CV 45.06

LSD All-Pairwise Comparisons Test of Plant Height(PH6) for Treatment

Treatment	Mean	Homogeneous Groups
T1	267.80	A
T4	186.37	A
T2	169.38	A
T3	155.86	A

Alpha 0.05
Critical Value for Comparison 140.45

Randomized Complete Block AOV Table for Plant Height(PH7)

Source	DF	SS	MS	F	P
Block	3	668.07	222.689		
Treatment	3	1773.73	591.242	19.35	0.0003
Error	9	274.93	30.548		
Total	15	2716.73			

Grand Mean 145.23 CV 3.81

LSD All-Pairwise Comparisons Test of Plant Height(PH7) for Treatment

Treatment	Mean	Homogeneous Groups
T4	155.29	A
T1	151.92	AB
T2	145.70	B
T3	127.99	C

Alpha 0.05
Critical Value for Comparison 8.8410

Randomized Complete Block AOV Table for Plant Height(PH8)

Source	DF	SS	MS	F	P
Block	3	580.33	193.444		
Treatment	3	296.43	98.811	1.35	0.3195
Error	9	660.14	73.349		
Total	15	1536.91			

Grand Mean 143.47 CV 5.97

LSD All-Pairwise Comparisons Test of Plant Height(PH8) for Treatment

Treatment	Mean	Homogeneous Groups
T2	150.17	A
T4	144.28	A
T3	139.88	A
T1	139.52	A

Alpha 0.05
Critical Value for Comparison 13.700

Randomized Complete Block AOV Table for Plant Height(PH9)

Source	DF	SS	MS	F	P
Block	3	274.97	91.655		
Treatment	3	1560.08	520.027	25.87	0.0001
Error	9	180.88	20.098		
Total	15	2015.93			

Grand Mean 147.40 CV 3.04

LSD All-Pairwise Comparisons Test of Plant Height(PH9) for Treatment

Treatment	Mean	Homogeneous Groups
T4	158.84	A
T1	153.87	A
T2	143.74	B
T3	133.13	C

Alpha 0.05
Critical Value for Comparison 7.1710

Randomized Complete Block AOV Table for Leaf Diameter(LD2)

Source	DF	SS	MS	F	P
Block	3	18.8689	6.28963		
Treatment	3	11.4061	3.80203	0.95	0.4566
Error	9	36.0073	4.00081		
Total	15	66.2823			

Grand Mean 5.0675 CV 39.47

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD2) for Treatment

Treatment	Mean	Homogeneous Groups
T2	6.4750	A
T4	4.9650	A
T1	4.4800	A
T3	4.3500	A

Alpha 0.05
Critical Value for Comparison 3.1995

Randomized Complete Block AOV Table for Leaf Diameter(LD3)

Source	DF	SS	MS	F	P
Block	3	12.2338	4.07795		
Treatment	3	1.4617	0.48723	1.20	0.3651
Error	9	3.6643	0.40715		
Total	15	17.3599			

Grand Mean 6.9259 CV 9.21

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD3) for Treatment

Treatment	Mean	Homogeneous Groups
T4	7.4238	A
T1	6.9100	A
T3	6.7100	A
T2	6.6600	A

Alpha 0.05
Critical Value for Comparison 1.0207

Randomized Complete Block AOV Table for Leaf Diameter(LD4)

Source	DF	SS	MS	F	P
Block	3	7.2701	2.42336		
Treatment	3	1.5929	0.53096	0.97	0.4475
Error	9	4.9154	0.54616		
Total	15	13.7784			

Grand Mean 8.4513 CV 8.74

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD4) for Treatment

Treatment	Mean	Homogeneous Groups
T4	8.9750	A
T1	8.3600	A
T2	8.3400	A
T3	8.1300	A

Alpha 0.05
Critical Value for Comparison 1.1821

Randomized Complete Block AOV Table for Leaf Diameter(LD5)

Source	DF	SS	MS	F	P
Block	3	3.55827	1.18609		
Treatment	3	1.88007	0.62669	2.22	0.1554
Error	9	2.54222	0.28247		
Total	15	7.98057			

Grand Mean 9.1062 CV 5.84

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD5) for Treatment

Treatment	Mean	Homogeneous Groups
T4	9.6250	A
T1	9.1250	AB
T2	9.0050	AB
T3	8.6700	B

Alpha 0.05
Critical Value for Comparison 0.8501

Randomized Complete Block AOV Table for Leaf Diameter(LD6)

Source	DF	SS	MS	F	P
Block	3	2.43230	0.81077		
Treatment	3	4.68510	1.56170	5.94	0.0162
Error	9	2.36650	0.26294		
Total	15	9.48390			

Grand Mean 9.3925 CV 5.46

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD6) for Treatment

Treatment	Mean	Homogeneous Groups
T4	10.145	A
T1	9.635	AB
T2	9.055	BC
T3	8.735	C

Alpha 0.05
Critical Value for Comparison 0.8202

Randomized Complete Block AOV Table for Leaf Diameter(LD7)

Source	DF	SS	MS	F	P
Block	3	5.4956	1.83187		
Treatment	3	3.5390	1.17967	7.14	0.0094
Error	9	1.4874	0.16527		
Total	15	10.5220			

Grand Mean 9.4550 CV 4.30

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD7) for Treatment

Treatment	Mean	Homogeneous Groups
T4	9.9200	A
T1	9.6850	A
T2	9.5400	A
T3	8.6750	B

Alpha 0.05
Critical Value for Comparison 0.6503

Randomized Complete Block AOV Table for Leaf Diameter(LD8)

Source	DF	SS	MS	F	P
Block	3	6.9321	2.31070		
Treatment	3	0.8541	0.28470	0.69	0.5813
Error	9	3.7201	0.41334		
Total	15	11.5063			

Grand Mean 9.0375 CV 7.11

LSD All-Pairwise Comparisons Test of Leaf Diameter (LD8) for Treatment

Treatment	Mean	Homogeneous Groups
T2	9.3400	A
T3	9.1350	A
T4	8.9650	A
T1	8.7100	A

Alpha 0.05
Critical Value for Comparison 1.0284

Randomized Complete Block AOV Table for Leaf Diameter(LD9)

Source	DF	SS	MS	F	P
Block	3	2.47210	0.82403		
Treatment	3	2.79410	0.93137	3.52	0.0622
Error	9	2.38410	0.26490		
Total	15	7.65030			

Grand Mean 9.2875 CV 5.54

LSD All-Pairwise Comparisons Test of Leaf Diameter(LD9) for Treatment

Treatment	Mean	Homogeneous Groups
T4	9.7900	A
T1	9.5550	A
T2	9.1000	AB
T3	8.7050	B

Alpha 0.05
Critical Value for Comparison 0.8233

APPENDICES C -YIELD PARAMETERS OF MAIZE

Table 6: Mean of Fresh Cob Weight

Treatment	Fresh Cob Weight(g)
Organic(T1)	193.89 B
Inorganic(T2)	160.10 BC
No Fertilizer(T3)	143.97 C
Organic +Inorganic(T4)	273.41 A
LSD	
CV	36.206
SE	16.005

Table 5: Mean of Dry Cob Weight

Treatment	Dry Cob Weight(g)/36M^2
Organic(T1)	134.28 B
Inorganic(T2)	113.17 BC
No Fertilizer(T3)	98.51 C
Organic +Inorganic(T4)	205.06 A
LSD	
CV	23.601
SE	10.433

Table 7: Mean of Number seeds/cob

Treatment	Number of Seeds Per Cob
Organic(T1)	398.45 A
Inorganic(T2)	383.35 A
No Fertilizer(T3)	376.10 A
Organic +Inorganic(T4)	387.55 A
LSD	
CV	41.150
SE	18.190

Table 8: Means Seed Weight Measured After the Study

Treatment	Seed Weight
Organic(T1)	81.05 B
Inorganic(T2)	81.88 B
No Fertilizer(T3)	77.33 B
Organic +Inorganic(T4)	130.08 A
LSD	
CV	14.400
SE	6.3654

APPENDICES D: ANOVA VALUES FOR GRAIN YIELD

Statistix 8.0
7/18/2013, 5:39:23 PM

LSD All-Pairwise Comparisons Test of Dry Cob(DRCB) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	205.06	A
1	134.28	B
2	113.17	BC
	398.51	C

Alpha 0.05 Standard Error for Comparison 10.433
Critical T Value 2.262 Critical Value for Comparison 23.601
Error term used: REP*TREATMNT, 9 DF
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of Fresh Cob(FCB) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	273.41	A
1	193.89	B
2	160.10	BC
3	143.97	C

Alpha 0.05 Standard Error for Comparison 16.005
Critical T Value 2.262 Critical Value for Comparison 36.206
Error term used: REP*TREATMNT, 9 DF
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of Number of Seeds(NS) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
1	398.45	A
3	387.55	A
2	383.35	A
4	376.10	A

Alpha 0.05 Standard Error for Comparison 18.190
Critical T Value 2.262 Critical Value for Comparison 41.150
Error term used: REP*TREATMNT, 9 DF
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of Seed Weight(SW) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	130.08	A
2	81.88	B
1	81.05	B
3	77.33	B

Alpha	0.05	Standard Error for Comparison	6.3654
Critical T Value	2.262	Critical Value for Comparison	14.400

Error term used: REP*TREATMNT, 9 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.

APPENDICES E: Below and Above Ground Biomas

Statistix 8.0
12:16:09 AM 8/11/2013,

LSD All-Pairwise Comparisons Test of Dry Root Weight(DRW) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
1	30.153	A
4	30.075	A
2	28.920	A
3	20.880	B

Alpha 0.05 Standard Error for Comparison 0.9901
Critical T Value 2.262 Critical Value for Comparison 2.2397
Error term used: REP*TREATMNT, 9 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of Dry Biomas(DRYBMS) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
1	168.35	A
3	167.60	A
2	167.05	A
4	166.35	A

Alpha 0.05 Standard Error for Comparison 6.6499
Critical T Value 2.262 Critical Value for Comparison 15.043
Error term used: REP*TREATMNT, 9 DF
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of Root Length(RL) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	26.425	A
3	25.300	A
1	23.975	A
2	22.750	A

Alpha 0.05 Standard Error for Comparison 2.0347
Critical T Value 2.262 Critical Value for Comparison 4.6029
Error term used: REP*TREATMNT, 9 DF
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of Dry Biomas(DBMS) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	119.13	A
3	118.98	A
1	117.56	A
2	116.43	A

```
Alpha                0.05      Standard Error for Comparison  3.1198
Critical T Value    2.262      Critical Value for Comparison  7.0574
Error term used: REP*TREATMNT, 9 DF
There are no significant pairwise differences among the means.
```

LSD All-Pairwise Comparisons Test of Root Weight(WETRW) for TREATMNT

TREATMNT	Mean	Homogeneous Groups
4	66.000	A
2	65.800	A
1	65.300	A
3	56.325	B

```
Alpha                0.05      Standard Error for Comparison  1.5462
Critical T Value    2.262      Critical Value for Comparison  3.4976
Error term used: REP*TREATMNT, 9 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.
```

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13/03/2013……………………

Date:

CLIENT: MR FUSEINI (AGRIC COLLEGE)

CHEMICAL PROPERTIES

Labels	pH1:1 H_20	% Org C	% Total. N	% Org. M	Exchangeable me/100g Cations				TEB	Exch.A (Al+H)	E.C.E .C	% Base	BD g/cm^3
					Ca	Mg	K	Na					
	7.41	1.33	0.13	2.29	10.68	2.1 4	0.3 6	0.09	13.27	0.05	13.32	99.62	1.43
	7.54	1.01	0.08	1.74	8.01	1.8 7	0.1 9	0.05	10.12	0.05	10.17	99.50	1.43

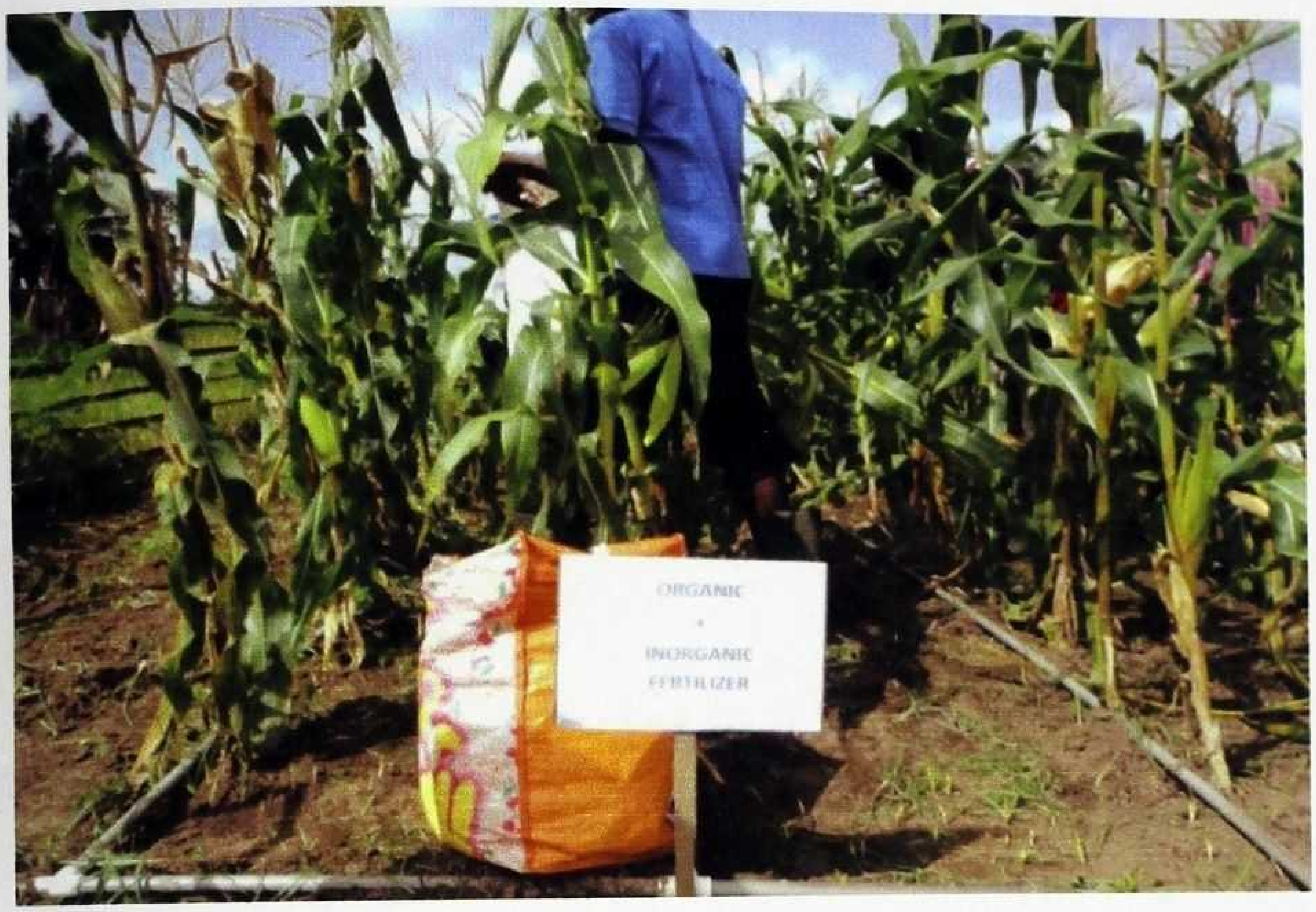
PHYSICAL PROPERTIES

Available-Bray's			Mechanical Analysis (%)			Texture
Ppm P	Ppm K		Sand	Clay	Silt	
683.27	68.65		66.34	4.04	29.62	sandyloam
580.44	57.83		65.02	4.02	30.96	Sandyloam

ANTHONY ABUTIATE

……………………….
(CHIEF TECHNOLOGIST)

APPENDIX F: PICTURES FROM EXPERIMENTAL FIELD


ORGANIC
INORGANIC
FERTILIZER