# EFFECT OF MEXICAN SUNFLOWER (*Tithonia diversifolia*) MULCH ON THE GROWTH AND YIELD OF MAIZE (Zea mays L.)

BY


**JIDE OLUWAROTIMI GODWIN**

**SLM/11/0041**


**A PROJECT REPORT IN THE DEPARTMENT OF SOIL SCIENCE AND LAND RESOURCES MANAGEMENT SUBMITTED TO THE FACULTY OF AGRICULTURE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF**

**BACHELOR OF AGRICULTURE**

**of the**

**FEDERAL UNIVERSITY OYE EKITI**

**SEPTEMBER, 2016**

## ABSTRACT

Greenhouse study was conducted at Federal University Oye- Ekiti, Department of Soil Science and Land Resources Management between June and August 2016 to compare the growth and yield of maize (*Zea mays* L.) using different rates of organic (*Tithonia diversifolia)* and Inorganic fertilizer. The effect of the amendments on the soil chemical properties was also evaluated. The experiment was laid out in a Completely Randomized Design with four replications. *Tithonia diversifolia* was applied at 10 and 20t/ha and inorganic fertilizer applied at 2000kg/ha and 400kg/ha. Plant growth parameters were taken at 2, 4, 6 and 8 weeks after planting. Results of Plant height, stem girth, Number of leaves, leaf length, leaf width, biomass accumulation and nutrient uptake showed that growth and yield of maize were significantly ($P<0.05$) different with *Tithonia diversifolia* soil amendments compared to inorganic fertilizer.

**Keywords**: *Tithonia diversifolia*, Inorganic fertilizer, Biomass accumulation, Nutrient Uptake, maize

**Word count: 137**

## ACKNOWLEDGEMENT

My profound gratitude goes first to God Almighty who gave me the strength, health and ability to accomplish this work. To Him be glory, honour and adoration forever, Amen. I also appreciate my supervisor, Dr. A.K Oluleye, his educative and prompt supervision, guidance, useful suggestions, constructive and objective criticisms and constant encouragement led to the successful conclusion of this work.

My heartfelt appreciation goes to my Dad (Mr Funsho Jide) and Mum (Funmilayo Jide) for their care and unceasing effort to ensure that I become the best I could be in life. You have been wonderful blessings in my life and I cannot find words to express my gratitude for all you have done for me. May you live long to eat the fruit of your labour (Amen).

My hearfelt gratitude goes also to my siblings: Taiwo, Kehinde, Iyanuoluwa and Morenikeji for their acceptance, love and unceasing prayer. To my cousins: Mr Wale Osanipin, Sikiru, Amina, Odunayo, Abiodun, Seun and Naomi, I say thank you all.

I also appreciate the contributions of my God sent helper, Dr Adewale Daniel. May Almighty God reward your love, care and support during the analytical stage of this work. Furthermore, my thanks goes to my able lecturers: Prof A. S. Fasina, Prof J.O. Agbeni, Dr Oluleye, Dr Ogunleye, Dr Uchenna, Mr Omoju and all the laboratory technologists, especially Mr Saheed for their positive effort towards the success of this research.

I also want to acknowledge the unique assistance, encouragement and love from my friends and well wishers: Adetoyi Femi, Alawaye Kunle, Gbaja Christianah and my beloved friend: Olosunde Opeyemi Busayo.

Finally, I want to appreciate the support and fellowship of entire members of Bethel Baptist Church, especially Reverend and Mrs J. A. Ilori for their prayer and assistance.

## CERTIFICATION

This is to certify that this research was carried out by JIDE OLUWAROTIMI GODWIN in the Department of Soil Science and Land Resources Management, Federal University Oye Ekiti.

**Supervisor's signature**

**Dr Anthony K.Oluleye**

11-10-2016

Date

**Head of Department**

**Prof. A.S. Fasina**

11/10/2016

**Date**

# DEDICATION

I gratefully dedicate this work to Almighty God.

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# CHAPTER 1

## INTRODUCTION

Maize (Zea mays L.), is perhaps the most domesticated of all field crops (Onwuenne and Sinha, 1991). Its center of origin was not certain but it probably originated from Guatamal or Mexico (Chapman, 1976). It was introduced into West Coast of Africa early in the 16$^{th}$ century, probably including Nigeria, by the Portuguese (Obi, 1986). All over the world, Maize has become an important and highly versatile arable cereal crop widely distributed, as an integral part of human diet and livestock feed, commonly consumed in both fresh and cooked. The processed forms are starch, corn syrup from corn starch, corn meal, corn flakes, custard, golden morn, maize slurry for pap production e.t.c. Ojo (2000) reported that among cereals, maize ranks the third most important crop after sorghum and millet in Nigeria. Akande (1994) reported that the domestic uses of maize demand of 3.5 million metric tonnes per anuum outstrip supply of 2 million metric tonnes.

The short supply in production results from the declining soil fertility, and remains the main concern of food security problems in Nigeria (Kabir *et al.*, 1996). Soil fertility depletion on small scale holder farms has been the root cause of declining per capita production threatening food security. Recent surveys revealed that soils in Nigeria within which Ekiti is found have been impoverished with low level of Phosphorus, Nitrogen and to lesser extent Potassium, which has been a major constraint to agricultural production (Oluleye, 2007). This decline in soil nutrient stocks primarily results from continuous cultivation without adequate external inputs, which have the capacity to improve the nutrient of the soil and its productive capacity through improved structure, and organic matter buildup (Monicah *et al.*, 2013). In an attempt to combat the challenges of soil fertility depletion in this region, smallholder farmers adopted the use of inorganic fertilizers to improve soil fertility. However, only few farmers can afford the inorganic inputs/mineral fertilizers (Mugwe *et al.*, 2009). Kader, (2012) and Sekar, (2013) reported that the use of these inorganic inputs have limitations, through volatilization of nutrients, leaching, acidification, declining soil organic matter (SOM), and physical degradation.

Recent, research in Nigeria have indicated potentials of organic inputs, use of animal droppings and plant residues to improve soil fertility (Gachengo *et al.*, 2014). The major challenges facing farmers are the selection and appropriate use of animal droppings and plant residues to sufficiently release nutrients to meet crop requirements.

Tithonia, (Mexican sunflower) has been reported by scientists as the main weeds taken over from *chromoleana odorata.* Tithonia produces a lot of biomass and contains high amount of Nitrogen and moderate amount of other nutrients. It contains 50% more phosphorus than legumes, enough nitrogen and potassium to promote crop yields (Jenifer and Wanjiru, 2007). The plant is perceived a menace to the farmer for its ability to outgrow and choke young plants and cleared off farms.

The need for replacement of expensive imported inorganic fertilizers in Nigeria prompted this study, with the ultimate objective of improve organic input fertilizer application for growth and yield of maize.

Specifically the present study aimed at:

1. Evaluating Mexican Sunflower (*Tithonia diversifolia*) as organic inputs for crop production.
2. Evaluating the comparative advantage on the use of the organic fertilizer with reference to inorganic fertilizers.

## CHAPTER 2

## LITERATURE REVIEW

### 2.1Mexican sunflower (*Tithonia diversifolia*)

Mexican sunflower (*Tithonia diversifolia*) is one of the numerous indigenous wild plant species. Carter (1992) reported that it is an annual shrub belonging to the family Asteraceae and native to Mexico and Central America. It is a highly aggressive weed, which grows usually to a height of about 2.5m and adaptable to most soil (Olabode *et al.*, 2007). They are commonly found growing extensively in hedges, along road side, crop field and on wasteland taking over from *Chromoleana odorata* and constituting a nuisance on the farm, as it competes for available nutrient with economic crops. *Tithonia diversifolia* was probably introduced to Africa as an ornamental plant. It had been observed to be widely spread in Nigeria, on abandoned waste land, beside highway, waterway and cultivated farmlands (Babajide , 2008). It has become a problem in Nigeria, thus a significant agronomic and economic factor to optimum arable crop production especially in the southern guinea savanna zone (LordBanjou, 1991).

The significance of weed in agriculture especially in crop production is both positive and negative. As crop producers, man is often quick to highlight crop losses due to weeds resulting from competition, allelopathy, and adulteration of farm produce leading to inflation of cost of production among others (Akobundu, 1987 and Lavabre, 1991)

However, Tithonia is relatively high in nutrient concentrations and little is known to farmers about its potentials as a nutrient source to improve nutrient status and crop yields (Sonke, 1997). Olabode *et al* (2007) determined tithonia's N concentration as 1.76% (comparable to those of poultry and swine manure); P, 0.82% (compared to cattle manure 0.52%), K, 3.92% (compared to poultry and cattle manure: 1.8 and 0.95%, respectively).

Besides, it has low content of lignin (6.5%) and polyphenols (1.6%). It has been used successfully to improve soil fertility and crop yields in Kenya (Jama *et al.*, 2000), Malawi (Ganunga *et al.*, 1998), Nigeria (Ayeni *et al.*, 1997), Rwanda (Drechsel and Reck, 1998) and Zimbabwe (Jiri and Waddington, 1998).

**2.2 Micronutrients in Agriculture**

The soil micronutrients are elements that are essential to plant growth, but are of only minimal utilization, hence, they are referred to as "trace elements", in contrast to the macronutrients which comprise a proportionally large percentage of plant weight. These trace elements are Fe, Zn, Cu, Mn, B, Cl, Co and Mo. Except for chlorine, the dominant role of micronutrients are activators in numerous enzyme systems (Ulysses, 2007).

In soils with micronutrient deficiencies, the application of small quantities of these nutrients enhance crop production (Welch 1995, Mortvedt, 2003) while large quantities added to the soil may be harmful (toxic) to the plants and animal consuming the forage. This is unlike countries where shifting cultivation is a dominant practice and micronutrient deficiency problems have not been given much attention. This is probably because nutrient recycling through leaf litter decomposition maintains the required level of the micronutrients.

Ramakrishnan (2002) asserted that there is existence of multiple micronutrient deficiencies in developing countries which is gaining increasing recognition. These deficiencies are proven to have major adverse health consequences, contributing to impairments in growth, immune competence, mental and physical development, and poor reproductive outcomes (Viteri *et al*, 2002*)* that cannot always be reversed by nutrition interventions. There is good evidence that deficiencies and excesses of micronutrients and trace elements in soils have a profound impact on the well-being of plants and animals that depended on soil to thrive. Increase in the micronutrient and trace element content of cereal grains, has been attempted by enrichment of soil with fertilizers fortified with these minerals and trace elements. This appears to influence the selenium, iodine and zinc content in the cereal grain and, in the case of iron, to enhance the iron content of the leaves. However, the best studies showing this to be an effective strategy have been with the soil fortification of zinc through fertilizers. Gibson and Hotz (2002) have demonstrated an increase of almost double the zinc intake of children in north-east Thailand achieved through the application of zinc fertilizer to rice fields deficient in the element.

### 2.3 Role of Micro-nutrient in Plant nutrition and Soil fertility

Micronutrient deficiency is widespread all over the world because of the generally low levels of available micronutrients in agricultural soils, and also because of increased nutrient demands from intensive cropping practices (Alloway 2008). Jiang *et al* (2005) posited that human activities such as tillage, crop residue recycling, fertilization, pesticide application, and waste disposal affect soil physicochemical properties, and will lead to changes of micronutrients in soils. However, Uprety *et al.* (2009), Xu *et al* (2013) affirms that Organic manures are significant sources of micronutrients in agro-ecosystems.

### 2.4 Micronutrients availability in soils

Micronutrients are made available in the soil as a result of slowly weathering minerals. The micronutrients come from contaminant minerals within the common primary minerals. Many Cl and some B salts are water soluble. Zinc, Cu, Fe and Mn are more soluble in acidic solution (and hence more available in acidic soils), becoming less soluble as pH increases. In strongly acid soils, Mn, Zn and Cu may dissolve to form toxic concentrations that actually hinder plant growth (Michalski, 2003).

Boron is probably one of the most added micronutrients to correct a deficiency. This is a common need in humid areas, because available B can be leached whereas Zn and Fe are most often deficient in soils of arid regions especially on calcareous soils while Mn, Cu, and Mo deficiencies are less common in most soils (Tisdale et al, 1985). Fe and Mn are also commonly deficient in arid or calcareous soils (Chen and Barak, 2002; Mengel and Geurtzer, 1988). However, Hubota and Alloway (1982), Chen and Barak (2002) cautioned that although Fe deficiency is not commonly observed in crop plants and the tree crops grown in the arid regions, it is by no means confined to this region or alkaline soils. Rare incidence of micronutrient deficiencies in Africa in the past were attributed largely to the practice of shifting cultivation in traditional agricultural system and the use of local crop varieties which do not take up much nutrients from the soil. The fallow period associated with shifting cultivation probably permits replenishment of depleted micronutrients in soil (Heathcote and Stockinger, 1970).

**2.5 NPK Status of Ekiti soils**

Works carried out by researchers had led to categorization of soil available P. Adepetu (1986) reported that in South-Western Nigria soils, available P of less than 8 $mgkg^{-1}$ was regarded as low while values between 8 – 15 $mgkg^{-1}$ medium and above 15 $mgkg^{-1}$ was high. Other research workers have reported varying figures as critical Bray 1 soil test P for maize; 8 mg/kg (Adeoye and Agboola. 1985; Agboola and Corey, 1972), 15$mgkg^{-1}$ (Adepetu, 1998). The critical P value according to Agboola and Obigbesan (1974) and Adepetu (1983) in Nigeria soils lies between 6 and 20 mg/kg. Responses of P fertilization vary from one crop to another. For maize in savanna region a range of 50-60kg $P_2O_5$ $ha^{-1}$ had been reported for optimum yield by Lombin (1987).

In the work carried out by Agboola and Ayodele (1985) on soil test interpretation for Ekiti-Akoko soils, available P of 0-8.5 $mgkg^{-1}$ was regarded low, 8.5 – 12.5 $mgkg^{-1}$ medium and above 12.5 $mgkg^{-1}$ high. Also in a diagnostic survey of farming system practices of Ekiti- Akoko agricultural development project (Daramola, *et al.*, 1987) available P  1.5 $mgkg^{-1}$ was reported in Ekiti central, 14 $mgkg^{-1}$ in Ekiti East and 16.2 $mgkg^{-1}$ in Ekiti North.

However, in a survey of National Special Programme on Food Security (NSPFS) project site, in Ekiti state, by Project Co-ordinating Unit (PCU) of the Federal Department of Agriculture (FDA, 2002). The following available P contents of soils were recorded: Erinfun ranged between 1.04 – 6.21$mgkg^{-1}$ with the mean value of 3.49$mgkg^{-1}$, Iyin – Ekiti (2.58 – 5.68$mgkg^{-1}$), mean (3.80$mgkg^{-1}$), Osin-Ekiti (1.55- 5.16 $mgkg^{-1}$), mean (3.86$mgkg^{-1}$) and Eporo- Ekiti (1.03 – 6.84$mgkg^{-1}$) mean value (2.88$mgkg^{-1}$). These are considered low considering the (0-8.5$mgkg^{-1}$) established by Agboola and Ayodele (1985) in the soil test interpretation of Ekiti-Akoko project soils. These soils are highly deficient in soil available P with the findings of Agboola and Obigbesan (1974), Adepetu (1986) and Osiname (1979), which put critical P level of Nigeria soils between 6 and 20 $mgkg^{-1}$.

Adoption of best soil management practices (SMPs) for nutrient availability is the key to increase plant productivity (yield and quality), increase profitability, maintain or improve soil fertility and productivity, and contribute immensely to food security in the state (Aritoff, 2012). Makinde (2011) posited that the farmers in Ekiti state usually use blanket fertilizer recommendation. Farmers find it more convenient to apply fertilizer needs in one single dose. For this reason, the use of compound fertilizer 15-15-15 has been very widely adopted by 70% of the farmers. The use of inorganic fertilizer in maintaining soil fertility as reported by Ugwuja (2011) has however shows that some fractions of these farmers are reluctant to the application of fertilizers for crop production. There were multiple answers which illustrated why some of the farmers did not apply fertilizer at all or why they have not been applying it on a continuous basis.

Ugwuja (2011) reported the respondents indicated that it makes no difference whether they applied fertilizers or not, 24.2% indicated that it is too costly, 6.9% indicated that it is forbidden. Also, 27.6% of the respondents indicated that it is not easily available, 17.2% indicated that their land is already fertile, while 13.8% indicated that applying fertilizer will affect the taste of produce". For instance, Makinde (2011) quoting Agboola (1986) wrote that some of the farmers in the south who have refused to apply fertilizer to any farmland used in yam production because they have noticed that using fertilizer to grow yam changes the colour of the yam to brown during pounding. This predominant practice of the farmers robs many soils of the essential nutrients; a problem that could have been solved very easily by applying the particular soil amendment needed to a particular soil. He opined that development of soil testing centers within close reach of the farmers will enable them test the nutrient quantity of their soil, before knowing the specific amendment to apply.

**2.6 Importance of Maize in Nigeria Agriculture**

Nigeria is the 10th largest producer of maize in the world, and the largest in Africa, followed by South Africa (IITA, 2012; USAID 2010). While maize is grown in the entirety of the country (both yellow and white varieties), the North Central region, is the main producing area. Seventy percent of farmers are smallholders, with an average 5 ha area of cultivated land accounting for 90 percent of total farm input (USAID 2010). Maize in Nigeria is usually intercropped, with yam, cassava, guinea corn, rice, cowpea, groundnut, and soybeans.

Maize, on average, from 2005 to 2010, was the 5th most produced agricultural commodity, becoming the 3rd (by quantity) in 2009 and 2010, after cassava and yams. Most of the production was targeted to the domestic market, since a negligible proportion of the production is formally exported (FAOSTAT, 2012). However, informal trade does occur with neighboring countries, although detailed volumes are not available.

Ecological zones of production include mangrove swamp, deep water, irrigated lowland, rain fed lowland, and rain fed upland (WARDA 2008). Although the Guinea Savannah zone provides the best ecological condition for maize cultivation, maize is also grown in the Forest zone, the Derived Savannah zone and the Southern Savannah (USAID 2010).

Introduced to Nigeria in the 16th century, maize is the fourth most consumed cereal during the past two decades, compared to sorghum, millet and rice (FAOSTAT 2012). Being among the primary food staples, maize consumption is widespread across the country and among households of different wealth. It is widely used in the preparation of traditional foods. Main local dishes include pap, tuwo, gwate, and donkunu, with the cereal cooked, roasted, fried, ground, pounded or crushed form (Abdulrahaman et al., 2006). Following an upsurge in 1994 (35 $Kgyear^{-1}$), per capita consumption of maize in Nigeria underwent an overall decline throughout the 1990s, reaching the lowest by the year 2000 (17 $Kgyear^{-1}$) with an encouraging growth rate between 2001 and 2007(FAOSTAT, 2012).

Most of the national production aimed at human consumption. However, industrial uses (such as the brewery and feed industry) have been on the increase during the past decade: the percentage of total maize production used for feed has grown from 13 to 18 percent of total production (USDA, 2005-2010). A specific driver of the feed industry is the development of the poultry sector, as poultry feed represents 95-98 percent of the total feed produced in the country between 2005 and 2010 (USDA, 2005-10). The development of the poultry industry is one of the priorities of Nigeria's agri-business strategy and is in line with the imposition of bans on maize exports to ensure maize supplies to the poultry and feed industries.

According to IITA, maize demand in the country is estimated to increase 3.2 percent per year due a perspective growth of urbanization and population. IITA estimates that approximately 60 percent of maize produced in the country is used for industrial end uses both for human (flour, beer, malt drinks, cornflakes, starch, dextrose, syrup) and animal consumption, mainly poultry (UNIDO 2010).

In terms of maize types, yellow maize is mostly used for feed and human consumption, while white maize for human consumption only. IITA estimates that yellow maize production will likely increase considerably as compared to white maize in the coming years, due to the development of the feed sector (particularly poultry) (Hartwich, 2010). However, maize contribution to total feed production is small, and ranges between 11 percent in 2006 and 18 percent in 2010, given the high cost of maize as compared to other feeds. Maize grain is primarily used in layer and broiler feed ratios (Hartwich 2010).

### 2.7 NPK and Micronutrients use in maize cropping system

One of the problems of application of inorganic fertilizer in multiple cropping systems is the different nutrient requirement of the companion crops. This can be overcome by using unit fertilizer distributors.

Research has shown that K interacts with phosphorus (P) and that together they may interact with other nutrients. A good example is the observed reduction of P-induced zinc (Zn) deficiency of corn when available K levels are increased. Manganese (Mn) content of the corn plants also increases, indicating there is some relationship of K, P, Mn, and Zn in this complex effect resulting in less severe Zn deficiency. A more simple P-K interaction, but perhaps of more widespread importance, is their synergistic effect on yield. In these cases, besides their individual effects on yield, P and K together produced an extra 15 percent positive yield interaction for soybeans and 50 percent for Coastal bermudagrass.

**2.8 Fertilizer use in maize cropping system**

The importance of fertilizer as an agricultural input cannot be over emphasized particularly in the tropics where the nutrient levels of soils in most areas are low. Maize crop requires fertilizers in sufficient amount to give the maximum economic yields. There are two main types of fertilizer for improving crop productivity in Nigeria, inorganic (or chemical or synthetic fertilizers) and organic fertilizers. Ojeniyi (2002) reported that there are profuse evidences that inorganic fertilizers can improve yield of maize crop significantly. Cooke (1982) also asserted that fertilizers can improve soil fertility so that the yield of crops need no longer be limited by the amounts of plant nutrients that the natural system can supply and factors other than nutrition then set the limit to productivity. The advent of inorganic fertilizer has thus revolutionalized maize crop production through its provision of plant nutrients for improved maize crop productivity in Nigeria.

Total dependence on inorganic fertilizers however does not provide the panacea to soil management and crop productivity problems in Nigeria. According to Ojeniyi (1995) cited in Ojeniyi (2002) there are problems that arise with continuous use of inorganic fertilizers. Most farmers apply fertilizer without soil test, thus wrong amount and type may be applied. Deficiency of secondary and micronutrients occur in soil and crop, if the common NPK type is consistently used. Ojeniyi (1981) reports that total dependence on inorganic fertilizers may be accompanied by fall in soil organic matter, increased soil acidity and degradation of soil physical properties and structure and increased erosion.

The National Research Council (1989) cited in Lockeretz (1995) stated that in the past two decades, there has been increasing concern about agricultural damage to the environment and its consumption of non-renewable resources especially through synthetic pesticides and fertilizers. Agricultural chemicals have contaminated ground and surface waters, harmed fish and wildlife and greatly increased agricultural dependence on fossil fuel resources. The fore-going underscores the need to evolve alternative "reduced chemical" or "low-input" production systems involving a partial reduction in the use of chemicals.

### 2.9 Use of Organic fertilizer in Nigeria

Organic fertilizer are available in large quantities in Nigeria, readily available as waste from brewery fertilizers like molasses, waste from other industries can be considered as sources of organic fertilizers, other sources include materials such as cocoa pods, rice bran, bean pod, sorted town refuse, sewage and city waste, poultry droppings, animal dung, human feaces and urine. It also includes yam peelings, cassava peelings, and straws of rice, maize, millet, sorghum and sugar cane leaves. Inorganic fertilizer differ from organic fertilizers in that they usually consist of relatively simple chemical compounds of known composition and that they contain weight, much higher percentages of fertilizer elements (Lockeretz, 1995).

### 2.10 Importance of Organic inputs for Agricultural Sustainability

Michael (2010) affirmed that the use of organic materials is an important component for sustainable agricultural production. When such materials are applied to agricultural land they promote sustainability because of:

1. Their long term position effects on soil chemical and physical properties.

2. The possibility of recycling plant nutrients within a farm (e.g. feeding harvested fodder to livestock and then applying farmyard manure from these animal back to the land).

3. The possible substitution of readily available organic inputs for chemical fertilizer, and therefore a decreased dependence on external sources for costly fertilizer.

4. The general improvement in maize crop yield and quality obtained when adequate rates of organic soil amendment are incorporated into the soil. (Motavilli *et al*, 1994).

Ogbalu, (1999) reported plant wastes such as wood ash, spent grain, rice bran, and sawdust were effective as fertilizers. Effect was enhanced by amendment with pig, goat, cattle and poultry manure. The residue increased soil organic matter, N, P, Ca, Mg and pH and reduced soil bulk density. Chemical analysis showed that the residues contained N, P, K, Ca, Mg, Fe, Mn, Cu and Zn (Folorunso, 1999) and the manures increased soil pH, nutrient contents, growth and yield of maize and okra. Odiete *et al,* (1999) found that goat manure increased soil P and K yield of okra and amaranths. In the tropical world, plant- derived ash is regarded as a suitable manure and liming material (Ogbalu, 1999, Obi and Ekperigin, 2001).

In southeast Nigeria, planting of pepper and other vegetable at household levels is sustained by the use of chicken droppings, cow dung, wood ash and plant residues (compost) as sources of improving fertility of apparently depleted soil. According to Ogbalu (1999) these traditional sources of nutrients are accessible to farmers and the use of chemical fertilizers by villagers is not common. Apart from their direct effect as fertilizers, plant residues improve soil physical properties and fauna population. Recycling of plant residues will replace 40 to 50% of N exported by a crop, 25 to 40% of the P and 70% of the K. In the Nigerian savanna, about 3.1

million tones of crop residues are produced annually in form of sorghum, millet, cotton, maize, groundnut and cowpea. About 45% N, 40% P, 86%K, 92% Ca and 72% Mg removed from soil by crop are contained in the residues (Ogbalu, 1999). Therefore, recycling of agro wastes can be a good alternative to bush fallow. Unlike in case of chemical fertilizer, soil is physically and biologically built up, acidity is controlled and erosion is controlled.

The major constraints to the use of organic materials for maize crop production are competing alternative uses, bulk, time and the quality of organic materials. In addition to incorporation and as much as mulch, plant and animal remains are also used by farmers for fuel, housing, fencing, animal feed and for industrial purposes. These alternative uses invariably reduce the quantity of waste and residues being returned into the soil. The amount of organic matter needed to achieve most optimum maize crop productivity is enormous. Apart from the problem of returning the crop residue into the soil farmers often do not produce the quantity sufficient to maintain soil fertility and conserve the soil. The farmer must allow appropriate time between incorporation and planting to enable the maize crop to benefit from nutrient released from the organic matter. Failure to synchronize the time mineralization with crops needs will lead to waste of the nutrients. There may also be injury to the crops following heat on decomposition of freshly incorporated organic matter.

For crops to drive nutritional benefits from incorporated organic matter, it must be of high quality. That is, the carbon/nitrogen ratio of the organic matter being incorporated in the soil must be below 20:1 -25:1. The foregoing shows that to drive maximum benefit of organic materials incorporation, it may be necessary to accompany it with application of inorganic chemical fertilizer. This underscores the need for combined use of chemical and organic fertilizers for sustainable soil productivity under intensive continuous cultivation of maize crop in Nigeria.

# CHAPTER 3

## MATERIALS AND METHODS

### 3.1.0 General features of the study area

### 3.1.1 Geographical Location

The location of the soil samples for the greenhouse experiment was the Teaching and Research Farm, Ikole Campus of the Federal University Oye – Ekiti, Longitude (E 005$^0$29.573) and Latitude (N 07$^0$48.308) 340m above the sea level. This represent, Agro-Ecological Forest Zone of Ekiti State, Southwestern Nigeria.

### 3.1.2 Climate

In Ekiti state, the rainy season generally starts by March becoming fully established in May and ending in October. Although, there are yearly variation in the distribution and length of the rainy season, the average of several years' data indicated a bimodal rainfall pattern, with peaks in June and September. Temperature varies between a maximum of 36$^0$C and minimum of 25$^0$C, the low extremes coinciding with the rains and the cold-dry harmattan winds

### 3.1.3 Geology

The rock underlying the soils in this area are crystalline. Basement Complex formation consisting of gneisses, pegmatite schitsts and quartizites in between which are bodies of granites, syenites and intrusion of amphibolites or olivine rich dykes (Syrnth and Montgomery, 1962). The terrain of the Basement Complex is characterized by dissected etchplains, dotted residual hills, dome-shaped Iselbergs and long hogs back ridges (Oluleye, 2007)

### 3.1.4 Vegetation

As indicated under climate, the expected climax vegetation is the evergreen high forest composed of many varieties of hardwood timber, such as a procera Terminalia superba, Lophir, Khivorensis, Melicia excelsa and Antiaris africana. This natural vegetation is hardly present now but relics are observable, especially in the southern half of the state where some forest reserves are established by the government.

It can therefore be stated that the state is covered by secondary forest. To the northern part, there is the derived savanna. This is a woody savanna featuring such tree species as Blighia sapida, Parkia biglobosa, Adansonia digitata and Butyrospermum paradoxover most of the state, the natural vegetation has been very much degraded as a result of human activities, the chief of which is bush fallow farming system.

**3.2.0 Laboratory Analysis**

On soil samples the following laboratory analyses were conducted: pH (1: 1 soil, water ratio) particle size; sand, silt and clay, organic carbon, total N, available P (Bray-I-P), and exch. Cations (K, Ca, Mg and Na), the exch. Acidity (EA), the extractable micronutrients (Mn, Fe, Cu and Zn).

**3.2.1 The soil pH**

This was done using the potentiometric method (Mcclean, 1982). 20g of <2mm sieved sample weighed into 50ml beaker and 20ml of distilled water was added to the beaker. The suspension was stirred intermittently for 30 minutes and allowed to settle. The pH electrode of the pH meter was inserted into the partly settled suspension to take the pH reading.

**3.2.2 Particle size analysis**

The particle size analysis was done using Bouycous (hydrometer) method (Gee and Bauder, 1986). To each of the 50g of < 2mm sieved soil weighed into plastic bottles was added 100ml of calgon solution and the suspensions were stirred with a glass rod. 100ml of distilled water was added and shaken for ten minutes on a reciprocating mechanical shaker. The suspensions were poured into 1000ml of cylinders and made to the mark with water, ensuring that all the content of the plastic bottle was emptied. A thermometer was inserted into the suspension and temperature was recorded. The suspension was stirred and hydrometer reading was taken after 40 seconds. The suspension was allowed to stand for two hours after which the second hydrometer reading was taken. A blank reading was determined following the same procedure except that the soil was not added.

The texture was calculated thus:

$$\text{Percentage Clay} = \frac{\text{Corrected 2hrs reading - blank x 100}}{\text{Weight of soil}}$$

$$\text{Percentage Clay} = \frac{\text{Corrected 40seconds reading - blank x 100 - \% Clay}}{\text{Weight of soil}}$$

Percentage sand = 100 – (% clay + Silt)

### 3.2.3 Organic carbon determination

The organic carbon determination was done following the Walkely – Black (Chromic acid) method (Nelson and Sommer, 1982). Briefly, 1g of < 2mm sieved soil was weighed into 250ml volumetric flasks and 5ml of 1 N $K_2CrO_7$ were added to each flask using a pipette. 10 ml of concentrated sulphuric acid ($H_2SO_4$) was added. The suspensions were mixed thoroughly after which they were allowed to stand for 30 minutes and 100 ml water was added. Five drops of ferrous complex ($NH_4FE(SO_4)_2$) indicator were added to each of the suspension and titrated against 0.5 N ferrous ammonium sulphate solution until the end point (pink colour of suspension) was reached. Blank determination was made following the same procedure except that soil was not added.

$$\% \text{ Organic Carbon} = \frac{(B-T) \times 0.003 \times 1.33}{\text{Weight of sample}}$$

Where B = Blank reading

T= Tire reading

### 3.2.4 Total Nitrogen

The total N was determined using Macro-kjeldahl method (Jackson, 1958). 0.5g of finely grounded sample was weighed into 50ml Kjeldahl digestion flask. 1.1 g of $K_2SO_4$- catalyst and 3 ml of concentrated $H_2SO_4$was added. The flask was heated on a digestion block until frothing subsides. The heat was gradually increased until a clear digest was obtained. The mixture was further heated for another 3-5 hours. The flask was cooled and 20ml of distilled water was slowly added with shaking swirl. The whole digest was then transferred to a Kjeldahl distillation flask marked 80ml.

The total Nitrogen is calculated thus:

$$\text{Total N (mgkg}^{-1}\text{ soil)} = \frac{(X_3.\ X_1)\ 100}{X_2.Y}$$

### 3.2.5 The Available P

This was determined by Bray- 1 –P (Bray and Kurtz, 1945) method. 1g of air-dried <2m sieved soil samples was weighed into 50 ml centrifuge tubes with stopper and 7 ml of extractant (HCl-$NH_4F$ solution) was added to each. The suspensions were shaken for 1 minute and centrifuged at 3500rpm for 5 minutes. The suspensions were filtered to get a clear filtrate. 2 ml of the titrate was transferred into a 25ml container, 4 ml of the developer (a mixture of ammonium molybdate reagent and ascorbic acid solution) was added and the solutions were made to mark with water. The solutions were left for 10 minutes after which the colour development was measured in the same way.

The available phosphorus ($Mgkg^{-1}$) was calculated thus:

$$Mgkg^{-1} = \frac{R \times G \times VE \times DF}{W \times Aliquot}$$

Where, R = Abssorbance

G = Gradient of the standards

VE = Volume of extractant

DF = Volume of container

W = Weight of sample taken

### 3.2.6 Exchangeable Acidity

This was done using the method described by Juo (1979). 10g of the air – dried < 2mm sieved samples were weighed into a funnel fitted with a Whatman No-1 filter paper fixed into 100ml plastic bottles. The samples were leached with 100ml 1 N KCl solution and mixed thoroughly. 50 ml of the leachates were taken into a 250ml beaker and 5 drops of phenolphthaline indicator was added. The solutions were titrated with 0.1 N NaOH solution to a permanent pink end point and the titre values were recorded. Blank determination was also done following the procedure above but no soil was added.

$$\text{The exchangeable acidity } (Meq100g^{-1} \text{ soil}) = \frac{(T-B) \times NB \times VE \times 100}{W \times Aliquot\ taken}$$

Where T = Titre

B = Blank Reading

NB = Normality of base

VE = Volume of extract

W = Weight of soil taken

### 3.2.7 Cation Exchange Capacity and Effective Cation Exchange Capacity

Exchangeable cations were determined by IN NH40Ac at pH 7. The K was determined by the flame photometer, while Ca, Mg, and Na were determined by Atomic Absorption Spectrophotometer (AAS). The exchangeable cation capacity (CEC) was determined by the ammonium saturation method. The ECEC was then calculated as the sum of the exchangeable bases and exchangeable acidity (Juo, 1979).

### 3.2.8 Base saturation

Base saturation was calculated as the sum of the exchangeable bases expressed as the % of the CEC.

$$\% \text{ Base saturation} = \frac{K+Na+Ca+Mg}{CEC} \times 100$$

### 3.2.9 Extractible micro nutrient

The Extractible micro nutrient (Mn, Fe, Cu and Zn) were determined by extracting with 0.1N Hcl and read on AAS

### 3.3 Greenhouse study

The Greenhouse experiment was conducted in the soil samples from this location. (Ikole, Iwo series). Fertilizer application was done at the rate of 200kgha$^{-1}$, 400kgha$^{-1}$ for NPK 15-15-15 and Tithonia10tha$^{-1}$ and 20tha$^{-1}$ in 20pots of 5kg soil. A treatment without added fertilizer was included as a control. All treatments received basal nutrients. All samples were arranged in Completely Randomized Design (CRD) and irrigated daily to 60% field capacity. Four seeds of maize (Extra early 2008-SYN.E.E Y-DT STR) were sown at a depth of 2.5cm in each of the pot. The plant were grown for 8weeks and data collection such as stem girth, leaf number, plant height, leaf length, leaf width were taken at 2, 4,6 and 8weeks after planting. At each period plant samples were also harvested. The plant samples were cleaned with a clean moist cloth before taking the fresh weight and then dried in an oven at 70$^0$C to constant weight. After weighing, the dried samples were ground using cyclotec 1093sample mill. The plant samples were then analysed for N, P and K contents after digestion by a dry ash procedure of Chapman and Brat (1961). Phosphorus in the digest was measured by the Vanadomolybdate yellow colour method, Nitrogen and Potassium was also measured. N.P.K uptakes were determined by multiplying respective N.P.K contents with plant biomass.

All data were subjected to analysis of variance (ANOVA) using the general linear model of the SAS (1992). Means were separated using Duncan Multiple Range test (DMRT) and Least Significant Difference at 5% probability level.

Nutrient use efficiency of a plant generally referred to as fertilizer use efficiency for a standard genotype. More recently, it is defined as the ability of a cultivar to acquire nutrients from growth medium and/or to incorporate or utilize them in the production of shoot and root biomass or utilizable plant material (seed grain, fruit, and foliage) (Jothamani *et al* 2007, Oluleye, 2007).

Relative Agronomic Efficiency (RAE) is expressed as the additional amount of economic yield per unit of nutrient applied. This is calculated using this formula

$$RAE\ (\%) = \frac{Y(\text{test fertilizer}) - Y\ (\text{control})}{Y\ (\text{NPK}) - Y\ (\text{Control})}$$

Where:

Y (test fertilizer) = yield of test fertilizer($gpot^{-1}$)

Y (control)= yield without fertilizer ($gpot^{-1}$)

Y (NPK)= yield of reference fertilizer ($gpot^{-1}$)

RAE= Relative Agronomic efficiency (%)

# CHAPTER 4

# RESULTS AND DISCUSSIONS

4.1 Soil characteristics.

Results of the initial chemical and physical analysis are presented in Table 4.1. The detailed physico-chemical characteristics as shown revealed the soil pH 5.2 is slightly acidic. The classification of the soils collected for the greenhouse experiment and land use description revealed that the land use pattern was predominantly mosaic forest cropped principally to cassava/maize and yam in the upper crest of the slope. These soils maintained oil palm, Cacao and most food crops. The soil is classified as Alfisols, having good base saturation (more than 35% with a distinct/argillic (Clay accumulation B- horizon), slightly and moderately acidic, 1.5m below the top (Bromfield, 1967). According to local soil taxonomy, the soil belongs to Iwo series.

The soil is low in organic matter (12.45gkg$^{-1}$). The total N (0.74gkg$^{-1}$) is considered low, considering 1.0gkg$^{-1}$ critical level established by Metson (1961). The exchangeable bases in order of their abundance were Ca (0.78)> Mg> (0.30)> K (0.30) > Na (0.11C mol kg$^{-1}$ soil). The Ca was low considering critical levels of 2.0-2.6 C mol kg$^{-1}$ soil established by Agboola and Corey (1973) and 3.8 C mol kg$^{-1}$soil by Agboola and Ayodele (1987). Mg considered low compared to 1.9 C mol kg$^{-1}$soil established by Agboola and Ayodele (1987) and K high compared to 0.18-0.2 C mol kg$^{-1}$ soil by Agboola and Obigbesan (1974). The extractable micro-nutrients in order of their abundance were: Fe (85.57) > Mn (42.68) > Zn (4.46) > Cu (1.74mgkg$^{-1}$). The Mn was high with 25mgkg$^{-1}$ critical level by Agboola and Adeoye (1985). Cu was moderate with 1.2 – 2.0 mgkg$^{-1}$ critical level by Agboola and Corey (1973). Zn content high with

3.0 – 3.45 $mgkg^{-1}$ critic al level by Sobulo and Osiname (1981). High content of extractible micronutrients are toxic to plants and deleterious effects on plant nutrition.

The exchangeable acidity (0.15C mol $kg^{-1}$) was low. The CEC (1.65C mol $kg^{-1}$) is low compared with > 4 C mol $kg^{-1}$ critical level established by FAO (1979). The available P (2.18$mgkg^{-1}$) was deficient considering 8-25 $mgkg^{-1}$ critical level by Adepetu and Barber (1979). The low native available P in this forest soil could be attributed to low SOM which is characteristics of acid mineral soils of the Basement Complex as explained by Agboola and Oko (1976) and Mengel (1997)

4.1 Characteristics of soil used for the studies

| Properties | Value |
|---|---|
| pH $H_2O$ (1 : 1) | 5.2 |
| Organic Carbon ($gkg^{-1}$) | 7.2 |
| Soil Organic Matter ($gkg^{-1}$) | 12.45 |
| Total Nitrogen ($gkg^{-1}$) | 0.74 |
| Av. P Bray 1 ($mgkg^{-1}$) | 2.59 |
| Exchangeable Cations ($cmolkg^{-1}$) | |
| Ca | 0.78 |
| Mg | 0.30 |
| K | 0.30 |
| Na | 0.11 |
| Exch. Acidity | 0.15 |
| ECEC | 1.65 |
| Base Saturation % | 90.3% |
| Extractible micronutrients ($mgkg^{-1}$) | |
| Cu | 1.76 |
| Zn | 4.46 |
| Mn | 42.68 |
| Fe | 85.57 |
| Particle size ($gkg^{-1}$) | |
| Sand | 760 |
| Silt | 120 |
| Clay | 120 |
| Textual class | Loamysand |

**4.2 Chemical** properties Of *Tithonia diversifolia* used in the experiment.

The chemical composition of *Tithonia diversifolia* is shown in Table 4.2. With regard to the tissue nutrient concentrations when compared to reported values of other sources of organic matter, *Tithonia diversifolia* with 17.3gkg$^{-1}$ N was similar to poultry and swine manure in N concentrations (17.8gkg$^{-1}$ and 16.9gkg$^{-1}$, respectively) and higher organic matter (234.7gkg$^{-1}$) content than *chromolaena odorata* (Olabode *et al.*, 2007). This affirmed the findings Generose (2001) that *Tithonia diversifolia* is a high quality organic source. The tissue nutrient concentration of *Tithonia diversifolia* was also reported to be higher in P and K but lower in Mg concentration than all other plant material. Hence it is of importance to note that supplement Mg should be added to the soil when crops with significant requirements for the nutrient are planted. Carbon – Nitrogen ratio and crude fiber content of *Tithonia diversifolia* was observed to be low (8:1) compared to *Panicum maximum* and *chromolaena odorata* reported by Olabode *et al.*, (2007) indicating a faster rate of decomposition as affirmed by Ikpe and Powell (2014) that organic amendment with C: N ratio of 25 and below decompose and release nutrients faster than those above 25. Palm and Rowland (1997) reported that the low lignin content of *Tithonia diversifolia* also contributes to high biodegradability of the plant material.

Table 4.2: Chemical properties of Tithonia diversifolia

| Parameters | Value |
|---|---|
| pH | 7.8 |
| O.M ($gkg^{-1}$) | 234.7 |
| Nitrogen ($gkg^{-1}$) | 17.3 |
| Phosphorus ($gkg^{-1}$) | 38.4 |
| Calcium($gkg^{-1}$) | 31.2 |
| Magnesium($gkg^{-1}$) | 0.15 |
| Organic Carbon ($gkg^{-1}$) | 136.5 |
| C : N ratio | 9 : 1 |
| Crude fiber | 58.2 |

4.3 Effect of Fertilizer sources on maize growth

The plant height was highly significant ($P<0.0001$) during the growth period (Fig. 4.1). This trend indicated that each treatment released nutrients that enhance plant height of maize. The co-efficient of variation was low ranging from 0.32-0.81% (Figure 4.1). The significant differences in plant height showed that plant nutrients were made available for plant growth which was reflected in the rapid increase in the vegetative and reproductive growth stage of the maize plant. There was increase in plant height up to senescence. Generally, plant height was enhanced by different levels of nutrient application (organic or inorganic). However, the maize plant responded favourably to the *Tithonia diversifolia* (organic source) treatment compared to the inorganic fertilizer. *Tithonia diversifolia* applied at 20tha$^{-1}$ was the optimum. This may suggest that the organic residue may have contributed some micronutrients. This observation is in agreement with that of Leda *et al* (2009) who reported that the residual effect of organic fertilizer increased the height of cotton. OM concentration of Tithonia diversifolia in addition to macro nutrient also has and supplies micronutrients (Phiri *et al.*, 2001). The plant height of the maize was lowest at 400kgha$^{-1}$ rate (Fig 4.1). It can thus be inferred that inorganic fertilizer applied at 400kgha$^{-1}$ was luxury consumption and excessive which could affect the growth of plant.

Figure 4.2 showed effects of fertilizer sources in maize stem girth. Significant ($P< 0.001$) effect on stem girth was observed. Stem girth was significantly higher ($P< 0.001$) under fertilizer treatments than the control. The coefficient of variation was low ranging from 0.00 to 1.18%. This could be as a result of high uniformity among the population of the plant used as sampling unit in the experiment. All treatment had a significant ($P< 0.001$) effect on the stem girth however; *Tithonia diversifolia* at 20tha$^{-1}$ had the highest (Fig 4.2). The finding of this study agrees with Ademiluyi and Omotosho (2004) who reported that stem girth of maize were better under *Tithonia diversifolia* applied soil than under the NPK fertilizer. The lesser stem girth obtained on maize plant receiving $10tha^{-1}$ of *Tithonia diversifolia* treatment compared to $20tha^{-1}$ of same plant material could therefore be inferred to be below the quantity that could meet nutrient uptake for increase in stem girth of maize plant. Similarly, NPK fertilizer applied at $400kgha^{-1}$ gave higher stem girth mean value than the NPK fertilizer applied at $200kgha^{-1}$. This inferred that fertilizer application at higher rate gave a more robust stem girth; this could be due to higher availability/ abundance of nutrient for plant uptake. The result is similar to the findings of Quansah, (2010) who reported that inorganic fertilizers at higher rate ($300kgha^{-1}$ of NPK 15: 15: 15) did not significantly affect the stem girth of maize plant compared to the lesser rate ($150kgha^{-1}$) of the same fertilizer treatment.

Figure 4.3 shows the effects of fertilizer sources on the number of leaves. There was significant ($P< 0.001$) effect on the number of leaves for all the treatments. The coefficient of variation was low ranging between of 1.30-2.55%. From Fig 4.3, generally there was an increase in the number of leaves as plant ages increased. Treatment with *Tithonia diversifolia* at $20tha^{-1}$ had the highest number of leaves. However, the number of leaves under the higher NPK rate was not significantly ($P< 0.001$) different from the number of leaves produced under the control (Fig 4.3). Treatment with *Tithonia* component had same value at 8WAP and were significantly ($P< 0.001$) higher than inorganic fertilizer at $200kgha^{-1}$ and $400kgha^{-1}$. *Tithonia diversifolia* applied at $20tha^{-1}$ may be sufficient to release optimum nutrient quantity for leaf production for maize growth. Higher number of leave correlates with higher plant photosynthetic capacity. This observation disagrees with Leda *et al* (2009) who reported that the residual effect of organic based fertilizer with the exception of compost and Tithonia diversifolia significantly ($P<0.05$) increased the number of maize leaves over the control.

The effect of each of fertilizer sources on the leaf length showed Significant ($P<0.0001$) effect in the leaf length was observed in the maize plants throughout the period of growth (Fig 4.4). The treatments differs ($P<0.05$) significantly in leaf length with 400kgha$^{-1}$ application ranked higher than the 20kgha$^{-1}$rate of application (Fig 4.4). However, the lesser rate of application for the organic component (*Tithonia diversifolia*) had higher value than the inorganic component throughout the period except at 4 weeks after planting where the 200kgha$^{-1}$ rate of application of the inorganic fertilizer had higher value (29.13) than the 400kgha$^{-1}$ rate (28.43) of application for the inorganic fertilizer. Fig 4.4 shows that *Tithonia diversifolia* treatments contributed positively to the increased leaf length than the inorganic fertilizer and the control. According to Cassman and Pingali (2003), fertilizer alone cannot sustain increased leaf length of maize plant. However Adenijan and Ojeniyi (2005) reported increased leaf length of maize plant under soil amended with poultry manure than NPK 15: 15: 15. Tithonia diversifolia shows a greater capacity to release and retain nutrient necessary to enhance increase in leaf length of maize plant than inorganic fertilizer possibly due to increased organic matter it has contributed to the soil through decomposition of the plant material.

Fig 4.5 shows that significant ($P<0.0001$) differences on the Leaf width produced by maize plant at 2WAP. The highest leaf width was observed in *Tithonia diversifolia* treatment than the inorganic fertilizer and control which were however not significantly ($P<0.05$) different (Fig 4.5). Among the treatments, *Tithonia diversifolia* applied at 20tha$^{-1}$ gave the highest leaf width. This was closely followed by *Tithonia diversifolia* at 10tha$^{-1}$. This is in conformity with the finding of Olatunji, Ayuba and Ojeniyi (2012) that observed widest leaf width of cowpea for soil treated with poultry manure in their experiment to determine the effect of NPK and poultry manure on cowpea and soil nutrient composition.

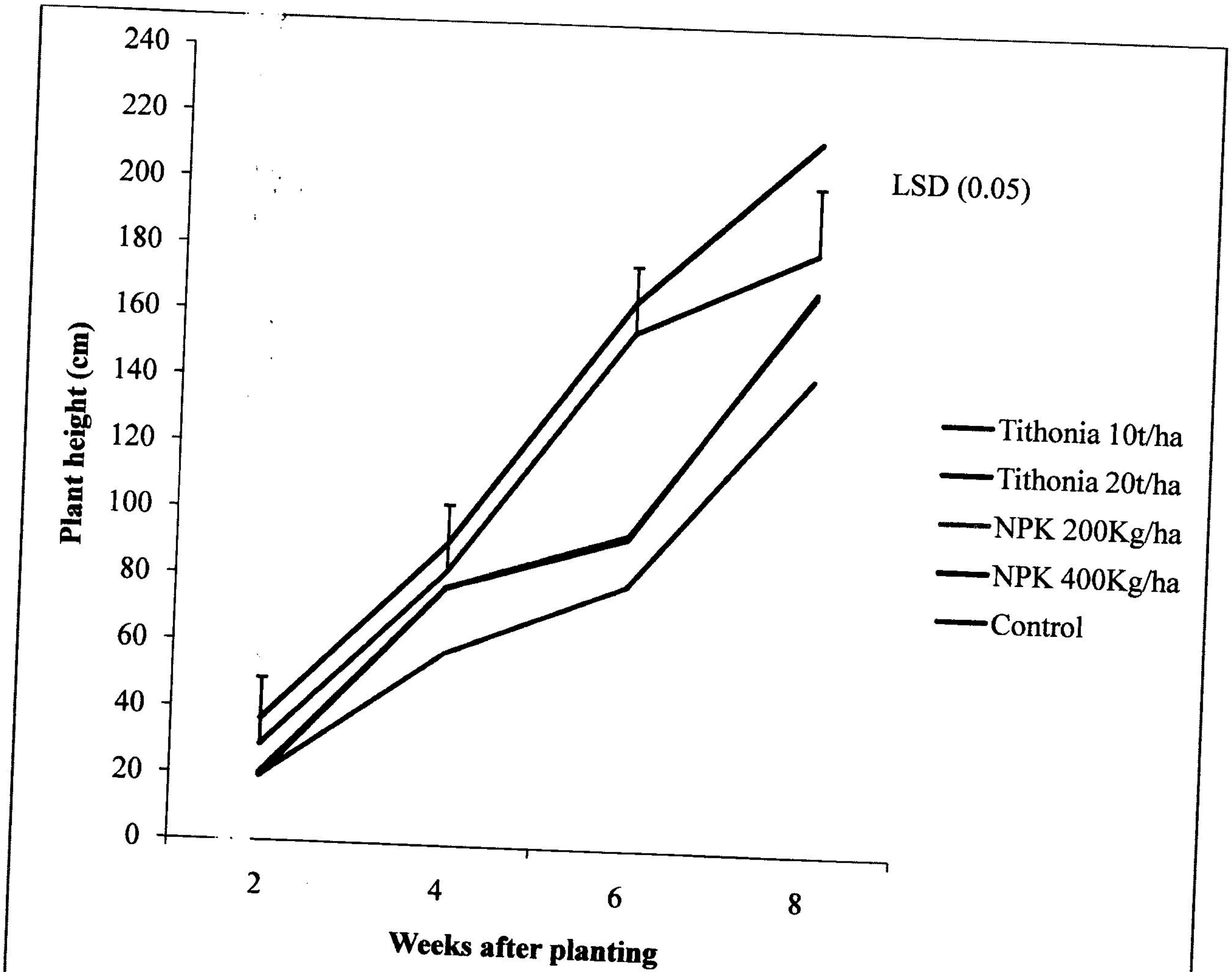


Fig 4.1: Effect of *thonia diversifolia* and inorganic fertilizer on Plant height (cm) of maize

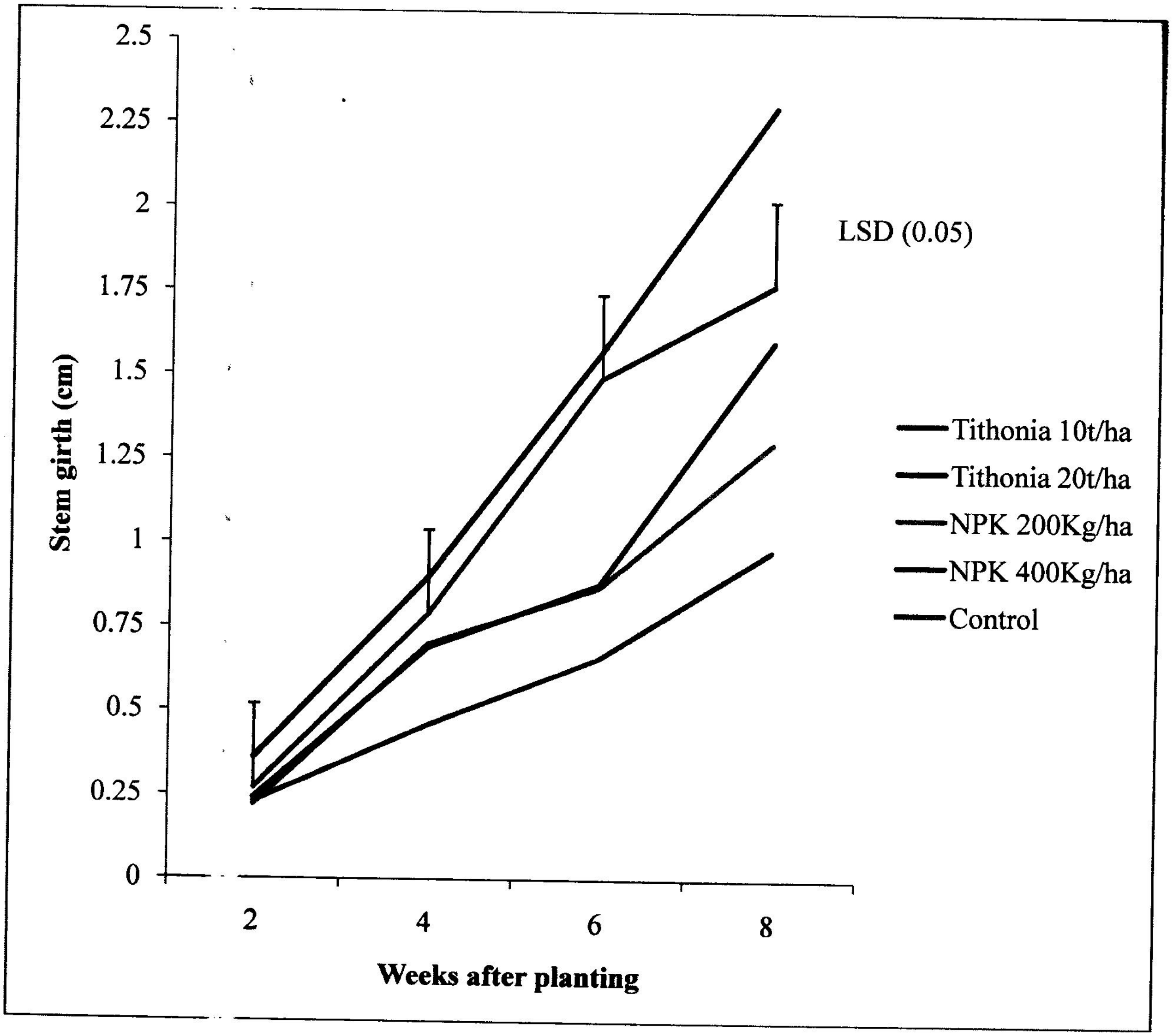


Fig 4.2: Effect of *Tithonia diversifolia* and inorganic fertilizer on Stem girth (cm) of maize

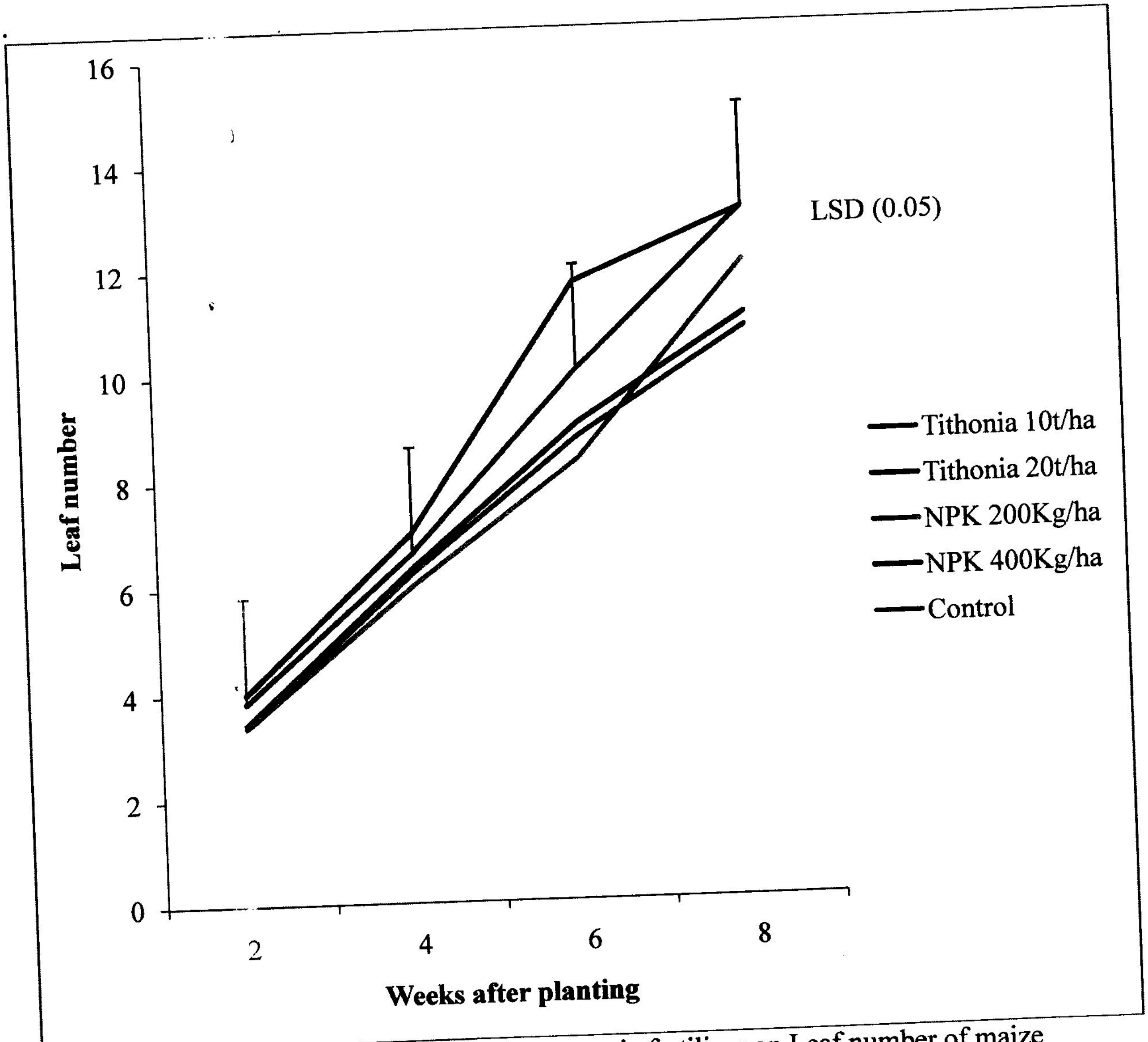


Fig 4.3: Effect of *Tithonia diversifolia* and inorganic fertilizer on Leaf number of maize

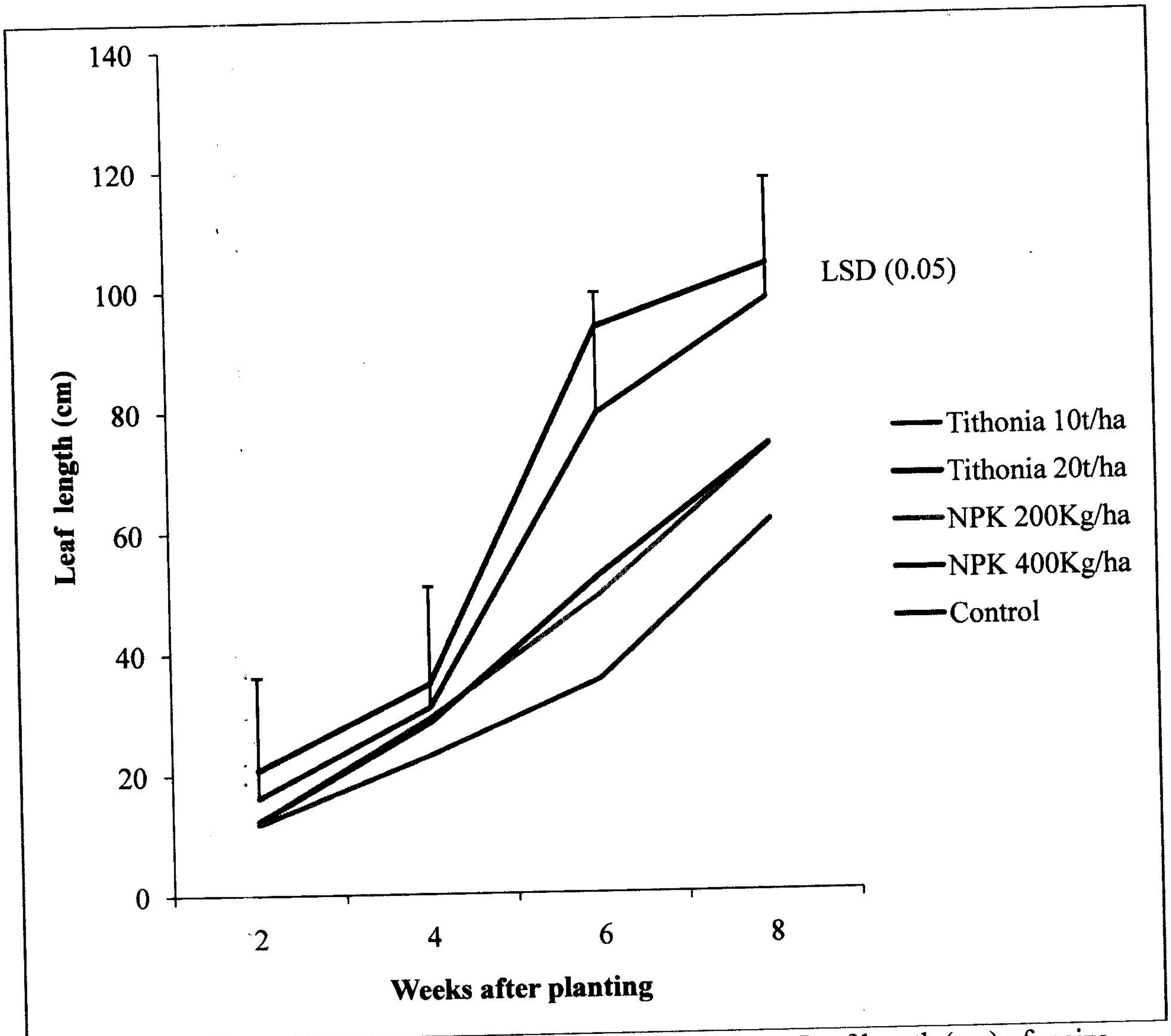

Fig 4.4: Effect of *Tithonia diversifolia* and inorganic fertilizer on Leaf length (cm) of maize

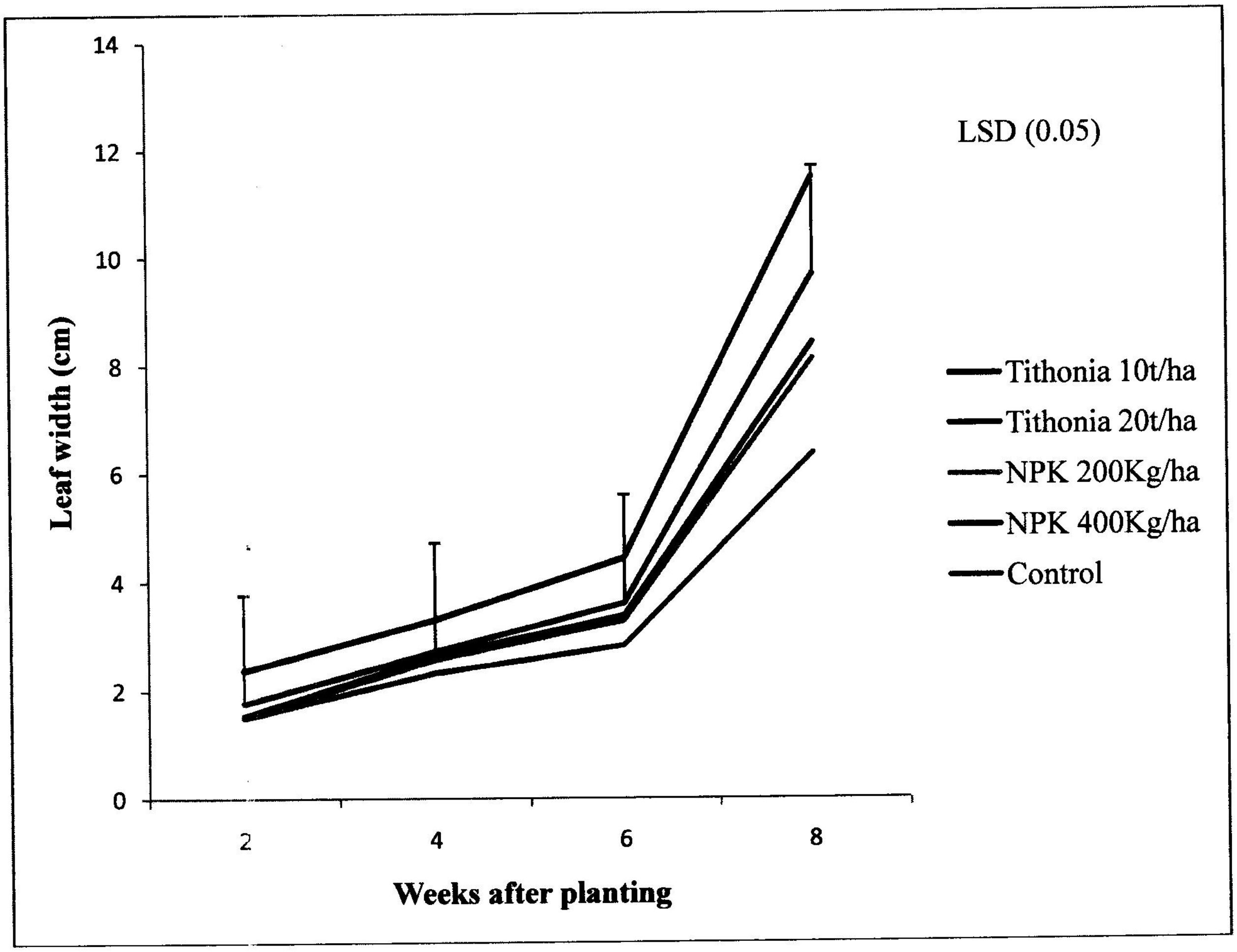


Fig 4.5: Effect of *Tithonia diversifolia* and inorganic fertilizer on Leaf width (cm) of maize

4.4. Dry matter accumulation

The effect of the fertilizer sources on dry biomass of maize is shown in Table 4.3. Significant ($P< 0.001$) treatment effect on dry biomass was observed on maize plant. The organic fertilizer treatments had significantly ($P< 0.05$) higher dry matter than the inorganic source and control throughout the growth period. The highest dry matter yield observed in *Tithonia diversifolia* treated plot could have resulted from increased mineralisation and adsorption of N, P, K (Bokhtair and Sakurai, 2005) which might have contributed to the dry matter accumulation of maize plant. Earlier reporters (Olabode *et al.*, 2007; Ademiluyi and Omotosho, 2007; Akanbi and Ojeniyi 2007) obtained similar results and remarked that biomass yield was supported by the incorporation of *Tithonia diversifolia* in the soil. On the other hand inorganic fertilizer applied at $400kgha^{-1}$ yielded lower biomass compared to $200kgha^{-1}$ of application and the control (Table 4.3). The $400Kgha^{-1}$ from this study was excessive and its influence on biomass yield was therefore negative. Furthermore, the remark of Epstein (1997) may equally be appropriate; because excessive nutrient could have antagonistic effect on plant development, make some nutrient unavailable etc.

Table 4.3: Effect of fertilizer sources on maize biomass production

| Fertilizer sources | Rate | Biomass | Produced | (g/pot) | |
|---|---|---|---|---|---|
| | | Weeks | After | planting | |
| | | 2 | 4 | 6 | 8 |
| **Tithonia** | $10tha^{-1}$ | $0.21^{b}$ | $2.75^{b}$ | $33.80^{b}$ | $92.17^{b}$ |
| **Tithonia** | $20tha^{-1}$ | $0.31^{a}$ | $3.89^{a}$ | $47.60^{a}$ | $120.50^{a}$ |
| **NPK Fertilizer** | $200kgha^{-1}$ | $0.12^{c}$ | $2.34^{c}$ | $24.50^{c}$ | $51.25^{d}$ |
| **NPK Fertilizer** | $400kgha^{-1}$ | $0.12^{c}$ | $2.31^{d}$ | $24.30^{d}$ | $51.25^{e}$ |
| **Control** | - | $0.11^{d}$ | $1.41^{e}$ | $17.80^{d}$ | $57.90^{c}$ |

**Means with** the same superscript in each column are not significantly different at $P < 0.05$.

### 4.5 Relative Agronomic Efficiency

Table 4.4 shows relative efficiency of *Tithonia diversifolia* relative to the in organic fertilizer. The RAE of *Tithonia diversifolia* is higher than that of the inorganic fertilizer. It could be inferred that the *Tithonia diversifolia* has a higher efficiency of additional amount of economic yield per unit nutrient applied. Bromfield *et al.* (1981) in a comparison of one time application of medium to high-reactive Minjingu PR and SSP in maize on acid soil in Western Kenya, reported a RAE for PR of only 26% one season and when examined over five successive seasons, however cumulative RAE for PR was 75%. It was clear from the better performance of maize DM yield in this study with *Tithonia diversifolia* relative to NPK and untreated soil, that the use of *Tithonia diversifolia* organic fertilizer sources as substitutes for the expensive soluble compound fertilizers is feasible in crop production.

Table 4.4: Agronomic Efficiencies of Mexican Sunflower in biomass production of maize relative to NPK

| Fertilizer sources | Rate | Relative Agronomic Efficiency (%) |
|---|---|---|
| *Tithona diversifolia* | $20tha^{-1}$ | 1041.35 |
| NPK Fertilizer | $400kgha^{-1}$ | 100.00 |

4.6 Nutrient uptake

Nutrient uptake effects of fertilizer sources on maize is shown in Table 4.5 at 4WAP. There were significant ($P<0.0001$) differences for Nitrogen, Phosphorus and Potassium uptake. Very low coefficient of variation in the range of 2.59 to 16.19% was observed. Nitrogen uptake ranked highest on maize plant under *Tithonia diversifolia* treatment. Thesame trend was observed for Phosphorus and Potassium showing higher significant ($p<0.05$) effect than inorganic treatment and the control.

The result indicated that the application of organic source registered higher nutrient uptake than the inorganic fertilizer and the control. Higher uptake of NPK nutrient due to application of Tithonia at 10t/ha and 20t/ha might result from ease of nutrient availability. The varying application rate (200kg/ha and 400kg/ha) of inorganic fertilizer was however not significantly different. This coincides with the result of Adeniyan (2003) who reported highest significant differences in nutrient uptake by maize plants sown under poultry manure than NPK fertilizer.

Table 4.6 showed the effect of fertilizer sources on nutrient uptake at 8WAP. The treatments significantly ($P< 0.001$) influenced the nutrient uptake by maize plant at the 8WAP. For N, P and K, the coefficient of variation was low in the range of 3.89 to 16.72%.

*Tithonia diversifolia* applied at the varying rate of 10t/ha and 20t/ha were observed to rank highest (Table 4.6). The findings that the varying application rates of *Tithonia diversifolia* increased the plant uptake for N, P and K indicate that the materials are good sources of plant nutrients. The organic materials are also able to retain plant nutrients for a longer time in the soil. The increased nutrient uptake and soil concentration of these materials suggests a direct effect of available nutrients for plant uptake. The nutrient uptake by maize plant from inorganic fertilizer at 200kgha$^{-1}$ and 400kgha$^{-1}$ at 8 WAP was however lower than organic source (*Tithonia diversifolia* incorporated at 10tha$^{-1}$ and 20tha$^{-1}$).

Table 4.5: Effect of fertilizer sources on NPK uptake at 4Weeks after planting.

| Fertilizer sources | Rate | Nutrient | Uptake | (g/pot) |
|---|---|---|---|---|
| | | Weeks | after | planting |
| | | N | P | K |
| Tithonia | 10t/ha | $2.28^{b}$ | $0.39^{b}$ | $9.07^{b}$ |
| Tithonia | 20t/ha | $3.50^{a}$ | $0.79^{a}$ | $13.70^{a}$ |
| NPK Fertilizer | 200kg/ha | $1.39^{c}$ | $0.21^{c}$ | $4.87^{d}$ |
| NPK Fertilizer | 400kg/ha | $1.39^{c}$ | $0.17^{c}$ | $5.33^{c}$ |
| Control | - | $0.73^{d}$ | $0.07^{d}$ | $2.21^{e}$ |

Means with the same superscript in each column are not significantly different at $P < 0.05$.

Table 4.6: Effect of soil amendment on NPK uptake at 8 Weeks after planting.

| Fertilizer sources | Rate | Nutrient | Uptake | (g/pot) |
|---|---|---|---|---|
| | | Weeks | after | planting |
| | | N | P | K |
| Tithonia | 10t/ha | $54.15^{b}$ | $4.83^{b}$ | $144.65^{b}$ |
| Tithonia | 20t/ha | $71.49^{a}$ | $11.44^{a}$ | $278.30^{a}$ |
| NPK Fertilizer | 200kg/ha | $26.13^{c}$ | $0.21^{c}$ | $10.47^{c}$ |
| NPK Fertilizer | 400kg/ha | $25.14^{c}$ | $2.15^{c}$ | $7.22^{cd}$ |
| Control | - | $23.58^{c}$ | $1.00^{c}$ | $4.35^{d}$ |

Means with the same superscript in each column are not significantly different at $P < 0.05$.

4.7 Variation in Post – cropping soil characteristics with fertilizer sources

Effects of varying rates of organic (*Tithonia diversifolia*) and inorganic soil amendment on soil chemical properties are presented in Table 4.7-4.10. The results obtained from the study showed that the application of the amendments improved soil pH with incorporated biomass of Tithonia diversifolia applied at 20t/ha giving the highest value for most of the parameters determined (Table 4.7). The Tithonia diversifolia treatments (*Tithonia diversifolia* incorporated at $10tha^{-1}$ and $20tha^{-1}$) significantly reduced soil acidity from strongly acid level of 5.2 (Initial value before experiment) to 5.9 and 6.1 respectively. This was within the range required for optimum growth of maize as reported by FAO (2002) and conforms to the findings of Ikpe *et al* (2001) that reported increased soil pH with acid sulphate soil amended with water hyacinth biomass. However, the inorganic treatments applied at $200kgha^{-1}$ and $400kgha^{-1}$ increased the soil acidity from 5.2 to 4.8 and 4.5 respectively (Table 4.7). The acidifying effect of NPK fertilizer can be ascribed to its acid-forming nature, which is due to its N and P content.

The soil Nitrogen content was also improved by Tithonia treatment from $0.74gkg^{-1}$ to the critical range reported by Gibson (1992) as $6.0\text{-}8.0gkg^{-1}$ compared to the inorganic fertilizer (Table 4.8). The same trend was observed for Phosphorus and Potassium with Tithonia giving the highest soil P and K content (Table 4.9 and Table 4.10).

Table 4.7 Variation in Post – cropping soil pH with fertilizer sources

| Fertilizer sources | Rate | Value | |
|---|---|---|---|
| | | Pre - cropping | Post cropping |
| Control | 0 | 5.2 | 5.1 |
| Tithonia | 10t/ha | 5.2 | 5.9 |
| Tithonia | 20t/ha | 5.2 | 6.1 |
| NPK Fertilizer | 200kg/ha | 5.2 | 4.8 |
| NPK Fertilizer | 400kg/ha | 5.2 | 4.5 |

Table 4.8 Variation in Post – cropping soil Nitrogen content with fertilizer sources

| Fertilizer sources | Rate | Value | |
|---|---|---|---|
| | | Pre cropping | Post cropping |
| Control | 0 | 0.74 | 1.0 |
| Tithonia | 10t/ha | 0.74 | 6.0 |
| Tithonia | 20t/ha | 0.74 | 6.2 |
| NPK Fertilizer | 200kg/ha | 0.74 | 5.6 |
| NPK Fertilizer | 400kg/ha | 0.74 | 5.0 |

Table 4.9 Variation in Post – cropping soil Phosphorus content with fertilizer sources

| Fertilizer sources | Rate | Value | |
|---|---|---|---|
| | | Pre cropping | Post cropping |
| Control | 0 | 2.18 | 1.56 |
| Tithonia | 10t/ha | 2.18 | 6.53 |
| Tithonia | 20t/ha | 2.18 | 6.61 |
| NPK Fertilizer | 200kg/ha | 2.18 | 2.41 |
| NPK Fertilizer | 400kg/ha | 2.18 | 2.32 |

**Table 4.10** Variation in Post – cropping soil Potassium content with fertilizer sources

| Fertilizer sources | Rate | Value | |
|---|---|---|---|
| | | Pre cropping | Post cropping |
| **Control** | 0 | 0.30 | 0.34 |
| **Tithonia** | 10t/ha | 0.30 | 4.52 |
| **Tithonia** | 20t/ha | 0.30 | 5.22 |
| **NPK** Fertilizer | 200kg/ha | 0.30 | 2.59 |
| **NPK** Fertilizer | 400kg/ha | 0.30 | 2.62 |

# CHAPTER 5

## SUMMARY AND CONCLUSION

The high cost of inorganic fertilizer and experimental implication such as eutrophication of surface water, lake, pond and wells prompted this present study for alternative of easily available and less expensive source of and environmental friendly organic fertilizers. The study evaluated the effectiveness of alternative organic fertilizer (Mexican Sunflower) for performance of maize through green house experiment.

The major findings of this research are summarized;

1. The soil of this study was low in soil organic matter, CEC, deficient in total Nitrogen, exchangeable potassium and plant available phosphate, well drained loamy sand.
2. When Mexican Sunflower and inorganic fertilizer were applied for maize, the optimum fertilizer application was $20tha^{-1}$ for sunflower and $400kgha^{-1}$ for inorganic fertilizer.
3. The highest biomass yields were obtained at the optimum fertilizer application rates.
4. The Relative Agronomic efficiency of the sunflower was higher than that of the inorganic fertilizer.
5. From the result of the study, it is concluded that *Tithonia diversifolia* could be substituted for maize production in this soil.

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## APPENDIX

Appendix 1: ANOVA summary for plant height of maize plant (cm) at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | PH2WAP | PH4WAP | PH6WAP | PH8WAP |
| Rep | 3 | 0.0041 | 0.2310 | 0.1093 | 1.290 |
| Treatment | 4 | 236.53*** | 583.50*** | 6270.32*** | 2713.34*** |
| Error | 12 | 0.0066 | 0.402 | 0.1584 | 1.8256 |
| Mean | | 25.01 | 77.48 | 118.09 | 175.50 |
| CV (%) | | 0.32 | 0.81 | 0.33 | 0.76 |

Means with the same superscript in each column are not significantly different at $P < 0.05$.

***=significant at 0.001, Trt = Treatments, Rep = Replications, CV= Coefficient of variability, PH2WAP= Plant height at 2 weeks after planting, PH4WAP= Plant height at 4 weeks after planting, PH6WAP=Plant height at 6 weeks after planting, PH8WAP= Plant height at 8 weeks after planting.

Appendix 2: ANOVA summary for stem girth (cm) of maize plant at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | SG2WAP | SG4WAP | SG6WAP | SG8WAP |
| Rep | 3 | 0.000026 | 0.000026 | 0.0000000 | 0.00016 |
| Treatment | 4 | 0.012570*** | 0.105480*** | 0.6677200*** | 0.99462*** |
| Error | 12 | 0.00001 | 0.000026 | 0.0000000 | 0.00016 |
| Mean | | 0.26600 | 0.708000 | 1.094000 | 1.59100 |
| CV (%) | | 1.18882 | 0.729375 | 0 | 0.81143 |

***=significant at 0.001, Rep = Replications, CV= Coefficient of variability, SG2WAP= Stem girth at 2 weeks after planting, SG4WAP= Stem girth at 4 weeks after planting, SG6WAP= Stem girth at 6 weeks after planting, SG8WAP= Stem girth at 8 weeks after planting.

Appendix 3: ANOVA summary for number of leaves of maize plant at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | NOL2WAP | NOL4WAP | NOL6WAP | NOL8WAP |
| Rep | 3 | 0.01444 | 0.003765 | 0.050000 | 0.050000 |
| Treatment | 4 | 0.33473*** | 0.585225*** | 7.127800*** | 4.550000*** |
| Error | 12 | 0.00662 | 0.007065 | 0.050000 | 0.050000 |
| Mean | | 3.60800 | 6.437500 | 9.550000 | 11.95000 |
| CV (%) | | 2.55650 | 1.305686 | 2.341432 | 1.871187 |

***=significant at 0.001, Rep = Replications, CV= Coefficient of variability, NOL2WAP= Number of leaves at 2 weeks after planting, NOL4WAP= Number of leaves at 4 weeks after planting, NOL6WAP= Number of leaves at 6 weeks after planting, NOL8WAP= Number of leaves at 8 weeks after planting.

Appendix 4: ANOVA summary for leaf length of maize plant at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | LL2WAP | LL4WAP | LL6WAP | LL8WAP |
| Rep | 3 | 0.008500 | 0.007906 | 0.006993 | 0.004845 |
| Treatment | 4 | 60.20612*** | 72.40993*** | 2315.951*** | 1283.970*** |
| Error | 12 | 0.010166 | 0.054260 | 0.006993 | 0.011170 |
| Mean | | 14.59100 | 29.31000 | 61.36300 | 82.11050 |
| CV (%) | | 0.691042 | 0.794744 | 0.136281 | 0.128715 |

*=significant at 0.05, **= significant at 0.01, ***=significant at 0.001, Rep = Replications, CV= Coefficient of variability, LL2WAP= Leaf Length at 2 weeks after planting, LL4WAP= Leaf Length at 4 weeks after planting, LL6WAP= Leaf Length at 6 weeks after planting, LL8WAP= Leaf Length at 8 weeks after planting.

Appendix 5: ANOVA summary for leaf width of maize plant at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | LW2WAP | LW4WAP | LW6WAP | LW8WAP |
| Rep | 3 | 0.00024 | 0.000565 | 0.000738 | 0.00000 |
| Treatment | 4 | 0.55172*** | 0.518020*** | 1.387975*** | 14.4894*** |
| Error | 12 | 0.000106 | 0.000640 | 0.000738 | 0.00012 |
| Mean | | 1.734000 | 2.711500 | 3.502500 | 8.80000 |
| CV (%) | | 0.595615 | 0.932997 | 0.775797 | 0.43522 |

*=significant at 0.05, **= significant at 0.01, ***=significant at 0.001, Rep = Replications, CV= Coefficient of variability, LW2WAP= Leaf width at 2 weeks, LW4WAP= Leaf width at 4 weeks after planting after planting, LW6WAP= Leaf width at 6 weeks after planting, LW8WAP= Leaf width at 8 weeks after planting.

Appendix 6: ANOVA summary for Dry weight (g) maize plant at 2, 4, 6 and 8 WAP

| | | Mean Square | | | |
|---|---|---|---|---|---|
| Source of variation | DF | DW2WAP | DW4WAP | DW6WAP | DW8WAP |
| Rep | 3 | 0.06 | 0.32 | 1.01 | 1.52 |
| Treatment | 4 | 0.02*** | 3.23*** | 534.98*** | 3806.21*** |
| Error | 12 | 0.04 | 0.08 | 0.11 | 0.21 |
| Mean | | 0.17 | 2.54 | 29.60 | 74.52 |
| CV (%) | | 3.93 | 0.70 | 0.21 | 0.15 |

***=significant at 0.001, Rep = Replications, CV= Coefficient of variability, DW2WAP= Dry weight at 2 weeks after planting, DW4WAP= Dry weight at 4 weeks after planting, DW6WAP= Dry weight at 6 weeks after planting, DW8WAP= Dry weight at 8 weeks after planting.

**Appendix 7: ANOVA Summary for Nitrogen uptake of maize plant at 4 Weeks after planting.**

| | | Mean Square | | |
|---|---|---|---|---|
| **Source of variation** | **DF** | **N_uptake4WAP** | P_uptake4WAP | K_uptake4WAP |
| **Rep** | **3** | **0.34** | 0.28 | 0.33 |
| **Treatment** | **4** | 18.28*** | 0.32*** | 79.42*** |
| **Error** | 12 | 0.02 | 0.02 | 0.03 |
| **Mean** | | 1.86 | 0.33 | 7.03 |
| **CV (%)** | | 3.49 | 16.19 | 2.59 |

**Appendix** 8: ANOVA Summary for Nutrient uptake of maize plant at 8 Weeks after planting.

| | | Mean Square | | |
|---|---|---|---|---|
| Source of variation | DF | N_uptake8WAP | P_uptake8WAP | K_uptake8WAP |
| Rep | 3 | 3.38 | 7.01* | 7.05 |
| Treatment | 4 | 1874.23*** | 289.88*** | 58950.36*** |
| Error | 12 | 5.96 | 0.51 | 12.03 |
| Mean | | 40.10 | 4.27 | 89.00 |
| CV (%) | | 6.08 | 16.72 | 3.89 |