# TRENCH DEPTH AND MULCH MATERIALS FOR LATE SEASON PLANTAIN PRODUCTION IN OWERRI SOUTH-EASTERN NIGERIA

**BY**

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**REG NO: 20094769468**

**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL**

**FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF**

**DOCTOR OF PHILOSOPHY (Ph.D) IN HORTICULTURE**

**JANUARY, 2016**

## CERTIFICATION

We certify that this work "Trench Depth and Mulch Materials for Late Season Plantain Production in South-eastern Nigeria" was carried out by Alagba Rosemond Adaohuru ( Reg. No: 20094769468) in partial fulfilment of the requirements for the award of Doctor of Philosophy (Ph.D) degree in Horticulture in the Department of Crop Science and Technology of the Federal University of Technology, Owerri.

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## DEDICATION

This thesis is dedicated to the honour and glory of God, my father, king, keeper, sustainer, provider, helper, preserver and redeemer, and to Jesus Christ my saviour and Lord.

## ACKNOWLEDGEMENTS

I highly appreciate the efforts of my principal supervisor, Professor J. C. Obiefuna for his articulate guidance, technical advice, fatherly and sustained tutelage and cooperation which l enjoyed from him throughout the investigation and preparation of this thesis. My sincere gratitude goes to Prof. I. I. Ibeawuchi (co-supervisor and former Head, Department of Crop Science and Technology) for his immense contributions, advice and encouragement towards the success of this thesis.

I also wish to appreciate Dr. O. P. Onyewuchi, my other co-supervisor and former Associate Dean, SAAT for her contributions, friendly advice and guidance throughout this research.

I wish to appreciate my senior colleagues, Dr. A. A. Ngwuta (immediate past Head, Department of Crop Science and Technology), Dr G. O. Ihejirika (the present Head, Department of Crop Science and Technology), and Dr. N. C. Adikuru for their support and contributions towards the success of this thesis. My sincere gratitude also goes to all the academic and non- academic staff in the Department of Crop Science and Technology. I also wish to appreciate Mr. Ogu my farm hand for his immense effort on the field during this research. Miss Sylvia Nwachukwu who also helped with my secretarial work is highly appreciated.

It is with great pleasure that I appreciate my husband Pastor Abayomi Alagba whose support I enjoyed throughout this research work. I also wish to appreciate my sweet girls Bukola and Rebecca Alagba who were very supportive and prayerful on my behalf throughout this research work. I also wish to thank my mum, Mrs. Juliet Iwuagwu and all my siblings for their prayers, support and encouragement towards the success of this research work.

Finally, my highest gratitude goes to God Almighty whose grace, strength, protection help, mercy and preservation were more than sufficient for me throughout the period of this research.

**ABSTRACT**

The major challenge in late season plantain production is poor field establishment followed by poor ratooning and high mat phenomenon. Proposed solutions include deep planting and mulching for soil microclimate moderation prior to the onset of early rains. The experiment evaluated the effect of three trench (planting) depths (60x60x60cm, 60x60x80cm and 60x60x100cm) and six mulch materials (trash, wood shavings, palm frond, saw dust, black polythene sheet and control) on late season plantain productivity in Southeastern Nigeria. The 3x6 factorial experiment was fitted into a Randomized Complete Block Design (RCBD) with three replications. The land was cleared manually. Planting depths were prepared, manured with poultry manure at 10 $tha^{-1}$. The trenches received 4 $tha^{-1}$ of appropriate mulch except black polythene. Two weeks later, plantain sword suckers were planted in December 2010. Core soil samples were collected at each trench depth for pre and post soil physico-chemical analyses, soil macro biological life count and percentage soil moisture determination. Soil temperature was monitored at each depth using soil thermometers. Growth and yield parameters for plantain were collected and analysed using Genstat. Mean separation was done using the least significant differences (LSD) at 5% level of probability. Planting depths and mulches significantly ($P<0.05$) reduced soil temperature and enhanced soil moisture content and sucker sprout. Plantain growth parameters (plantain height, girth, leaves, LA, LAI and sucker production) were significantly ($P<0.05$) enhanced by most mulch materials and trench depth/mulch sources interaction at 6, 9 MAP and at harvest respectively. Plantains planted in 80cm trenches and mulched with wood shavings fruited and matured significantly ($P<0.05$) early for both plant and first ratoon crops (308.80 and 650.00 days), produced heavy bunch weights (20.88 $tha^{-1}$,16.63 $tha^{-1}$), highest number of marketable hands/bunch (7.10 and 5.44) and marketable fingers/bunch (47.84, 32.23) respectively. Mulching plantains with wood shavings and sawdust in 60-80cm trenches significantly suppressed weeds and minimized black sigatoka severity for plant and first ratoon crops respectively. Deepest trenches mulched with black polythene stimulated most rapid mat rise (1.89cm/month). Input output cost analysis indicated that all plantains grown in mulched and unmulched trenches were all profitable enterprises with benefit cost ratio greater than unity. However plantains planted in 60-80cm trenches and mulched with wood shavings generated the highest economic returns to the farmer. At 6MAP, plantain growth parameters showed variable but significant positive and negative correlations with yield parameters (plantain bunch weight and number of fingers/bunch). However, at harvest, plantain growth parameters correlated positively and significantly ($P=0.05$) with plantain bunch weight and number of fingers/bunch, while correlating negatively and significantly ($P=0.05$) with days to 50% flowering and weed dry weight. The residual soil fertility after plantain first ratoon harvest for mulched and manured plantains was high. Late season plantains planted in 80cm trenches and mulched with wood shavings exhibited 81.90% establishment, proliferated the highest number of suckers, matured early and produced highest bunch yield (38.45 tons), gave the highest benefit/ cost ratio (5.06) per hectare and is therefore recommended to the farmers in Southeastern Nigeria. The implications for follow up crops in late season plantain production and further research work were discussed.

*Key words: trench depth, mulch materials, late season, plantain.*

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

In the rainforest agricultural system of South eastern Nigeria, the activities around tree and fruit crop production and their processing are the cornerstone of environmental and food sustainability. This is because of the multi-purpose roles trees play in the protection of the environment through carbon assimilation and release of oxygen ($O_2$) and at the same time produce food, fodder, fuel and shelter for man and livestock. The Southeastern Nigeria agroecology accommodates a lot of tree crop varieties such as palm, coffee, cashew, pear, apple, oranges, guava, mango, kola, banana and plantain etc. However, both the tree crops and other food crops such as cocoyam, maize and cassava are usually planted by farmers in their compound farms, probably because they are fast growing, early yielding and have high culinary preferences. One of the outstanding features in these compound farms is that more often than not, plantains and bananas are usually found intercropped with tree or other food crops within and around the homes. In Africa, however, plantains are the principal cultivated bananas that produce cooking bananas (CTA, 1987).

### 1.1.1 Soils

The soil (ultisol) of Owerri in Eastern Nigeria supports dense tree and food crop populations. The ultisol is characterized by low nutrient reserve, high subsoil acidity as well as other chemical constraints (Onweremadu *et al.,* 2007). Therefore, the need for soil amendments such as poultry manures and mulches become necessary to improve soil fertility, since plantains require good levels of fertile soils and high doses of organic manure for establishment, growth and yield. The high productivity of plantains under smallholder compound production system has always been attributed to enormous heavy applications of organic matter in the form of compound sweepings, livestock and kitchen wastes including miscellaneous waste water and wood ash thrown around the cultivation (Swennen,1990).

### 1.1.2 Production

Plantain features prominently in the farming systems of the rainforest belts of Nigeria which have favourable ecological conditions for the cultivation of the crop (FMAWRRD, 1989; Adelaja, 1997). In Northern Nigeria, where drought is a potential threat, plantain is grown in Fadama and valley bottoms where soil moisture condition is favourable for its growth (Adelaja, 1997).

Plantain production in Africa is estimated at more than 50% of worldwide production (FAO, 1990). It is estimated that about 70million people in West and Central Africa derive more than one quarter of their carbohydrate and one tenth of their caloric intake from plantains (Swennen, 1990), making plantain one of the most important sources of food energy through out African lowland humid forest, Asia, Central and South America (Ogazi, 1996; Nweke, 1996; Swennen, 1990; IITA, 1992).

### 1.1.3 Production systems

In compound production system, plantains are grown in various convenient points around the compound (Akinyemi *et al.,* 2010). The size depends on how much space is available in the compound, how many people in the household are interested in owning mats and the need of the household for numerous other possible compound tree crops. Bunch yield is usually high in this system and would be attributed to application of organic matter from household wastes (Nweke *et al.,* 1988; Robinson, 1996; Baiyeri *et al.,* 2004). This system is more predominant in the Southeastern part of Nigeria, where most compounds are within land limited areas owing to high population pressure (Eboh & Lemchi, 1994). This system accounts for 15-25% of total plantain production (Akinyemi *et al.,* 2010). The expansion of the cultivation of plantain in backyard system is limited and cannot meet the expected increase in demand for the crop (Obiefuna, 1986; 1987). This has led to field cultivation of the crop under continuous cropping where crop productivity usually declines after the first two or three years due to rapid reduction in soil fertility under humid tropical conditions (Braide & Wilson, 1980).

Other cropping systems in which plantains are intercropped with food and tree crops include taungya, multistorey cropping systems, plantain/cocoa intercrop (Akinyemi *et al.,* 2010; Agboola, 1982). In the taungya farming system, plantains and banana are grown with forestry species (e.g. *Gmelina arborea*, *Tectona grandis*). Here, the Musa spp. serve as a dual purpose crop, first as a nurse crop and second as a means of income before the maturity of the trees (Akinyemi *et al.,* 2010). The crops are phased out once the trees are established. This is commonly practiced in Ogun, Ondo, and Edo States. The prevalence of this system in the last 20 years is low, but it accounts for about 10% of the total production (Wilson, 1986; Akinyemi *et al.*, 2010).

In the Western States of Nigeria and in the Ikom area of Cross River State, where cocoa is an important cash crop, plantain/cocoa intercrop is practiced. In this system, plantain is planted alongside cocoa (*Theobroma cacoa*), where it serves as a nurse crop during early stages of development (Akinyemi *et al.,* 2010). In most instances, plantain production increases with expansion of the cocoa plantation (Adenikinju, 1983; Wilson, 1986; Baiyeri *et al.,* 2004). The prevalent bush plantain cropping system of the rain forest involves a complex mixture in which plantains are intercropped with many field crops such as cassava (*Manihot spp*), egusi melon (*Citrullus spp*), cocoyam (*Colossia esculentus*) and yam (*Dioscorea spp*) (Aiyelaagbe *et al.*, 2001).

In the last three decades commercial production under monoculture emerged and has rapidly increased in the last five years. Commercial plantain production is mainly in the Southern and Western States of Nigeria, which include Akwa-Ibom, Cross River, Imo, Enugu, Rivers, Edo, Delta, Lagos, Ogun, Osun and Oyo States (Ogazi, 1996). However, the management of the plantain orchards has been poor due to lack of technical knowledge of farmers and/or extension supervisor. The contribution of monoculture plantain is yet to be quantified (Akinyemi *et al.,* 2010).

### 1.1.4 Production trends

Plantains and bananas represent the world's second largest fruit crop with annual production of 129,906, 098 metric tons (FAOSTAT, 2010). They rank as the fourth most important global food commodity after rice, wheat and maize in terms of gross value of production (INIBAP, 1992). Nigeria is one of the world's largest producers of plantain (FAO, 2006). Despite its prominence, Nigeria does not feature among plantain exporting nations because it produces more for local consumption than for export (Akinyemi *et al.,* 2010). National per Capita consumption figures show its importance relative to other staples (FAO, 1986). However, plantain production in Nigeria has witnessed a steady rise for more than 20 years now (Aiyelaagbe, 2001). The country in 2004 produced 2.103 million tons harvested from 389,000 hectares (FAO, 2006).

This increase however, has not been without some depression in plantain production. The country experienced a great depression in plantain production between 1987-1988 and 1990 (FAO, 2005). This may be connected with the outbreak of black Sigatoka disease caused by *Mycospherella fijiensis*. The effort of all stake holders in combating the disease through release of improved/resistant cultivars might have been responsible for the steady rise in production. Between 1990 and 1994, production increased by 37%, ten years later, between 1995 and 2004, production increased by 0.47 million tons. The overall production has doubled in the last twenty years (FAO, 2006; Akinyemi *et al.*, 2010). The majority of plantains (82%) in Africa are produced in the area stretching from the lowlands of Guinea and Liberia to the central basin of the Democratic Republic of Congo and the West and Central Africa produce 61 and 21% respectively (FAO, 1986).

The yearly increase in plantain production has not been consistent over the last two decades, and average yield $ha^{-1}$ has remained constant. Between 1990 and 1999, for example, average yield was $7tha^{-1}$ signifying consistency in intensity of cultivation for ten years (Akinyemi *et al.,* 2010). The land area cultivated increased by 40% between 1999 and 2000 (FAO, 2005). Though the production during this period increased by 0.67million tons, the yield $ha^{-1}$ dropped from 7to 5 $tha^{-1}$, indicating that the increase came from an increase in extensity of cultivation that was experienced ten years earlier (FAO, 2005; Akinyemi *et al.,* 2010).

**1.1.5 Uses**

Plantains (*Musa spp.* AAB) are plants producing fruits that remain starchy at maturity (Mariot & Lan-caster, 1983; Robinson 1996) and need processing before consumption. They can be fried, baked, boiled (and then sometimes pounded) or roasted, and consumed alone or together with other foods.When cooked, plantains are extremely low in fats, high in fiber and starch, low in cholesterol and salt. An average sized plantain when cooked contains 50-80 grams of carbohydrates, 2-3 grams of protein, 4-6 grams of fibre, 0.1-0.3 grams fats. It is rich in potassium which is good for the heart and helps to prevent heart attacks and hypertension. It is also a good source of magnesium, phosphorous, vitamins A, B and C and good for weight loss. Unripe plantains are good for diabetic patients because they contain complex carbohydrates which are released slowly (African Food Company, 2002).

In Nigeria, soymusa, a baby food from plantain flour (60%) has been made and used (Ogazi *et al.,* 1991; Ogazi 1996). Flour made from ripe plantain has been used in making bread, biscuits and instant flour (Ngalani & Crouzet, 1995). Jams, mamalades, juice, vinegar, beer and alcohol can be made from ripe plantain fruits. Furthermore, plantain peel meal can be successfully included in broiler rations up to 7.5% beyond which it is detrimental (Ogazi, 1996). Also in tropical zones of Colombia, plantains are not only an important part of human diet but the fruits furnish indispensable feed for domestic animals as well (Morton, 1987).

In Nigeria therefore, plantain has become an important food crop with immense potentials to improve food security and job creation from the point of view of its value chain of production, processing, utilization and marketing (Obiefuna *et al.*, 2014) The versatility of plantain crop in the kitchen and its potential as an industrial raw material for the production of baby weaning food makes the crop an important one in Nigeria.

## 1.2. Problem statement

The major limitation of the late season plantain planting appears to be poor crop establishment and low survival percentage, especially when the rains end unexpectedly early. Plantain is also very sensitive to moisture stress and drought, especially during floral or reproductive phases. There is therefore the need for mulching (Obiefuna, *et al.*, 1983), and irrigation (Morton, 1987) during the dry season. In Nigeria, there is a continual shortage of plantain fruits during the off-season usually January to June. Subsequently, the prices of plantain tend to rise. In the humid tropics, commercial orchard plantain is usually grown during the early planting season (March-April) when food crops are grown (Obiefuna, 1983). This results in abundance of plantain fruits between July and December. The commodity becomes scarce from January through June. This creates a hunger gap between the early season and next early season. The shallow roots, the heavy weight of the inflorescences and strong winds result in lodging (bending of bearing plants), doubling (pseudostem breaks), snapping off (corm breaks leaving part on the ground) or uprooting also called tip over or toppling (the entire corm with roots comes out of the ground) (Swennen, 1990). This is further worsened by the upward growth of the plantain mat (high mat) with time which exposes the plantin roots. The result is yield reduction over time (Obiefuna, 1985). Soils of Southeastern Nigeria are low in nutrient reserve, highly acidic and poorly buffered and need to be improved through organic amendments which are environmentally friendly and sustainable.

## 1.3. Objectives

The broad objective of this research is to explore the appropriate planting depth and mulch materials for boosting survival, establishment and yield of late season plantain establishment The specific objectives of this study are to;

(i) determine the effect of trench depth and mulch on survival, establishment, growth and yield of late season plantain;

(ii) determine the effect of trench depth, and mulch on soil biological life during the late season plantain establishment;

(iii) assess the effect of trench depth and mulch on soil physico-chemical properties in plantain establishment;

(iv) ascertain the effect of trench depth and mulch on plantain protection and diseases during the plantain life cycle;

(v) attempt an input-output cost analysis of late season plantain cropping using different trench depths and mulches.

## 1.4 Justification

Plantain cultivation is not without its problems and constraints. In rainfed agriculture most food crops are cultivated during the early season. Demand for labour is high and competitive, labour shortage exists. In most cases labour shortage makes cultivation of large farms difficult, resulting in delayed weeding and reduced yield (Akinyemi & Makinde, 1999). Plantains produced in small fields under shifting cultivation and bush fallow experience rapid yield decline after few production cycles (Wilson, 1987). This yield decline syndrome observed after one or two years of cropping has been implicated as a major obstacle to plantain cultivation in West and Central Africa (Aba *et al.,* 2011). This has been blamed on low levels of soil organic matter and the increased susceptibility of traditional cultivars to several pests and diseases (Braide & Wilson, 1980), particularly Black Sigatoka leaf spot (caused by *Mycospherella fijiensis*) which causes up to 30-50% yield reduction (IITA, 1989). Most plantain cultivars are susceptible to Black Sigatoka leaf spot disease. Observations in plantain producing regions showed that the disease occurred more in distant fields than in home gardens (Aba *et al.,* 2011).

For optimum growth and fruit yield, plantains require high amount of nutrients which are often supplied only in part by the soil (Swennen, 1990). Consequently, several inorganic fertilizer combinations have been recommended for optimum yield of plantains. However, inorganic fertilizers are too expensive (Akinyemi *et al.,* 2010), highly politicized and often scarce for subsistence farmers. Soil acidification with consequent yield decline after a few years of continuous use have been reported as detrimental effects of mineral fertilizers on the strongly weathered, poorly buffered soils of the tropics (Kang & Balsubramanian, 1990). There is also low nutrient use efficiency as a result of losses through volatilization and leaching (Aba *et al.,* 2011). Management methods that decrease requirements for agricultural chemicals are needed in order to avoid adverse environment impacts (Bilalis *et al.,* 2009)

Furthermore, plantain roots are shallow, not well developed and superficial (Swennen, 1990). The inflorescence is positively geotropic, so that it is pendent (Morton, 1987). Deep planting has been reported to reduce exposure of shallow roots of plantain to drying out and subsequent tip over (toppling) and wind damage (Obiefuna, 1985).

There has been little or no change in the cultural practices of the crop in the last 20 years. The inadequate knowledge of improved cultural practices of the crop by farmers, inefficient extension service system by government, and skewness of specialization in areas of research are part of the reasons why yield potential of plantain is still low in Nigeria (Akinyemi *et al.*, 2010).The interplay of the above mentioned challenges result in reduced level of plantain production which leads to reduced yield or out put per unit of land and increased cost per unit of fruit.

Soil fertility management on small scale farms in the tropics has become a major issue as a result of continued land degradation and rapid population growth (FAO, 1981). Major arable soils are often poorly suited to high input agriculture involving the use of chemical fertilizers, pesticides and herbicides. Maintaining and improving soil quality is crucial if agricultural productivity and environment quality are to be sustained for future generations (Reeves, 1997). Thus, there is need for incorporation of organic amendments such as poultry manure to the soil. Farmers can take many actions to maintain, improve and rebuild their soils, especially soils that have been under cultivation for a long time. This can be achieved by maximizing the retention and recycling of organic matter (FAO, 2005). Animal manure (poultry manure) is a valuable source of crop nutrients and organic matter, which can improve soil biophysical conditions thereby making the soil more productive and sustainable (Ihejirika *et al.*, 2009).

Mulching reduces soil temperature, increases soil life, in filterability and water retention in the soil (Salau *et al.*, 2003). It enhances vegetative growth and increases bunch yield in both first and second year crops in plantain (Obiefuna, 1985; Shiyam *et al.*, 2010). Mulch materials such as saw dust, wood chips, palm frond, palm bunch refuse and trash are cheap and easily affordable by farmers. (Obiefuna, *et al.*, 2014; 1980), and add nutrients to the soil on decomposition. Saw dust and wood shavings have residual effects and last for up to 10 years (Staufer, 2002) after application. Addition of organic materials of various origins to soil has been one of the most common practices to improve soil physical properties (Wikipedia, 2013).

In traditional systems, pits of varying depths are dug, sometimes for dumping refuse and plantains are planted in these pits (Onwuzu & Nweke, 1983). Household wastes, wood ash waste, animal droppings and waste water are dumped in the holes around the plantain mat all year round (CTA, 1987; Obiefuna, 1990; Ogazi, 1996). The yields are high and consistent, and have been estimated at 30-50$tha^{-1}$ (Nweke *et al.*, 1988; Ogazi, 1996). At shallow depth, losses have been recorded due to lodging (Obiefuna, 1984), inadequate soil moisture supply, drying up of the exposed roots, pests and diseases particularly nematodes and black sigatoka leaf spot disease (Banful *et al.*, 2000; Swennen, 1990). Most small holder farmers who lack funds to procure modern inputs of fertilizers and chemical only apply organic manures (Obiefuna, 1990).

Trench depth of 30 x 30 x 30cm has been recommended by Swennen (1990). Shallow planting depth could cause the plants to dry out and induce a superficial root system in the mother plant and suckers (Robinson, 1996). However standard trench depth for plantain is 60 x 60 x 60cm (CTA, 1987; Obiefuna 1983). At this depth it becomes necessary that various measures should be taken to alleviate the yield declines in plantain and this can partly be achieved by use of soil amendments such as poultry manure and mulches, especially during the dry season to conserve moisture. Furthermore, the use of deeper trenches, insitu manure and mulch application (deep in the trenches) at planting and use of props to support the fruiting plants may reduce the bending of friuting plants. Deeper trenches may imply that the superficial roots will take a longer time to reach the soil surface and the danger of exposure to desiccation is reduced.

It is assumed that a combination of appropriate poultry manure rates, proper mulching and mulch materials and deeper trenches for planting may go a long way to addressing some of challenges associated with plantation production and yield decline. This will be particularly beneficial in plantains cultivated in the dry season. Based on plantain life cycle, the fruits will also be sufficiently available and affordable all year round. The natural resource base will be maintained and farmers will have all year round income.

Improvement through crop survival can be obtained through moisture conservation management and soil temperature control during the dry season (Obiefuna, 1987). From the foregoing scenario, it was therefore reasoned that the application of appropriate mulch as a cheaper alternative to irrigation could help conserve moisture, reduce high soil temperature and improve poor crop establishment during dry season for improved survival and yield of late season plantain.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Origin and world distribution of plantain /bananas

The origin of plantain and its introduction to Africa have generated controversy among researchers and taxonomists (Ogazi, 1996). According to Stover & Simmonds (1987), all wild Musa species are native to South and Southeast Asia and the coast of India to Papua New Guinea. No date can be assigned to their domestication (Norman *et al.*, 1996). Edibility first evolved in wild *Musa acuminata* and all edible diploids are still widely but thinly spread through South East Asia and Melanasia. There is no evidence of edibility evolving within *Musa balbisiana* (Norman *et al.*, 1996). However, Ogazi (1996) reported all edible bananas to originate from the wild species *Musa acuminata* Colla and *Musa balbisiana* Colla.

A number of theories have been forwarded as to how and when the spread of plantains to Africa took place. The most popular concept being that plantain was introduced to Africa by Arabs (Ogazi, 1996). However De langhe (1996) noted the impossibility of this as the movement of Arabs to Africa appeared too recent to justify the extent of production, utilization and variation of plantain in Africa. He noted that due to the greater diversity in the cultivars of plantain found in Africa than Asia, significant evolutionary changes in plantain must have occurred in Africa and noted the probability of plantain being in the continent before the Bantu invasion of 7,000-8,000 B.C. Available evidence indicate that the mechanisms which gave rise to the large diversity in plantain found in Africa include natural hybridization, somatic mutation and evolutionary development especially in inflorescence and parthenocarpy (Ogazi,1996). In another report, Norman *et al.* (1996) noted that plantains were probably taken to the East coast of Africa from Indonesia, rather than from India, the likely date being approximately 1500 BP. Around the same time, they also moved eastward into the Pacific.

The commercial plantain and banana industry developed in the West Indies and Central America in the nineteenth century, based largely on the AA types Gros Michel and various mutant members of the Cavendish group. With the spread of Panama disease (*Fusarium oxyporium and Fusarium cubens*) and later Sigatoka leaf spot (*Mycospherella musicola*), programmes to breed disease resistant cultivars developed. (Norman *et al.*, 1996). Shortly after the introduction from South East Asia, plantain was generally integrated into the farming system of the humid forest zone of Africa, between $4^0$ 30´ N to $8^0$ 10´ N (Obiefuna, 1984), where it has acquired considerable nutritional and economic significance (Swennen & Vuylsleke, 1991; Oritz & Vuylsleke, 1996).

Countries producing more than 1.8 million metric tons of plantain and bananas include Uganda, India, Brazil, Colombia, Ecuador, Philippines, Rwanda, Indonesia, Zaire, China, Mexico, Venezuela, Coasta Rica, Thailand, Burundi and Tanzania (Norman *et al.*, 1996). Major producers however are Uganda, India and Brazil. Morton (1987), reported that world production of plantain was 28 million metric tons; 65percent from Latin America, 27% from Southeast Asia, India being the largest producer in Asia. However Norman *et al.* (1996) and Morton (1987) reported that Africa produces 70 percent and 71 percent of world production respectively with 161,878 hectares produced entirely for domestic use. Indonesia produces over 2 million tons for export, the Philippines 2 million tons, exporting mostly to Japan. Taiwan produces over ½ a million tons for export, while Central Africa (mainly Cote d'Ivoire and Somalia) grows nearly a million tons of plantain each year and exports large quantities to Europe. In South America, Brazil is the leading producer with about 3 million tons per year while Colombia and Ecuador are leading exporters. Venezuela crop in 1980 reached 983,000 tons (Morton, 1987). Green plantains are the basic food of the people of Western Soamoa and large quantities are exported (Norman *et al.*, 1996).

In Puerto Rico, plantain is the most important starchy food and is third in monetary value among agricultural crops, being valued at 30,000,000 dollars annually (Morton, 1987). In tropical zones of Colombia, plantains are produced on a total land area of about 420,000 hectares with a yield of 5,500 tons per hectare (Morton, 1987).

In Africa, plantains are grown for home consumption. The area between the lowlands of Guinea and Liberia in West Africa and the Central Basin of Zaire in Central Africa produces one half the world's total output of plantain. West Africa produces two thirds and central Africa one fifth of the African output (Swennen, 1990).

### 2.2. Taxonomy of plantain

The cooking plantains or sweet bananas belong to the genus Musa in the family Musaceae. The genus comprises about 40 species, all perennial. Wild *Musa species* are all diploid, with X =10 or X=11, though there are few doubtful species with X=7 or 9 (Stover & Simmonds, 1987).

The great majority of cultivated plantains are derived from two species of Eumusa group, *Musa accuminata* and *Musa balbisiana* and are triploid (2n=3x=3). Although in earlier literature the sweet bananas were designated as *Musa sapienta* L. and *Musa paradisiacal* L., the taxonomy of edible plantains is so complex that following Stover & Simmonds (1987) specific names have been abandoned and all are now designated by their genome component (Norman *et al.,* 1996).

There are three major groups; AAA, AAB, ABB, (A, acuminata genome; B, balbisiana genome). Including somatic mutants, there are perhaps 500 recognizable clones in existence, including also AA, AB, AABB, AAAB and ABBB. AAAA clones which have only been produced by breeding. The types of plantains grown and consumed as local subsistence food are derived from all three of the major groups (Burden & Coursey, 1997).

1. AAA: Mainly types with low starch and low sugar content when ripe and which if cooked, are cooked green. This group includes red bananas for cooking.
2. AAB: The true plantains which are generally starchy even when ripe and are usually eaten cooked.
3. ABB: Starchy cooking and eating plantains that are found in banana growing areas under a wide variety of names (Norman *et al*, 1996).

**2.3. Importance of plantain**

Plantains and bananas (Musa spp L.) are the most important tropical fruit crops (Ortiz *et al*., 1998). The consumption and demand for plantain within Nigeria is high and has increased in recent times, with supply struggling to meet demand (Akinyemi *et al.*, 2010). This is due to improved socio-economic conditions in both urban and rural communities despite the high prices occasioned by short supply, poor and inefficient production system (Obiefuna, 1991). This is such that plantain production is fast deteriorating in most producing countries. Thus a significant proportion of the world production is targeted at complementing the domestic requirements of producer nations with about 10% left for export (Adelaja, 1997). In Nigeria in particular, this has hampered the status of this crop as a foreign exchange earner (Akinyemi *et al.*, 2010). It remains an important staple food as well as a raw material for many products. Plantain occupies a strategic role in rapid food production, being a perennial ratoon crop with a short gestation period. The crop ranged third among starchy staples after cassava (*Manihot esculenta*) and yam (*Dioscorea spp.*) (Akinyemi *et al.*, 2010). Though fruits are produced all year round in home gardens, the major harvest comes in the dry season (November to February), when most other starchy staples are unavailable or difficult to harvest. Thus, it plays an important role in bridging the hunger gap (Wilson, 1986), as well as assisting farmers to have cash at hand through the sales of plantain. In Nigeria, plantain dried peels are used for soap production, while the dried leaves, sheath and petioles are used as tying materials, sponges and roofing material (Akinyemi *et al.,* 2010; Ogazi, 1996). Plantain leaves are also used for wrapping, packaging, marketing and serving of food (Ogazi, 1996).

In comparison with the situation in the past three decades where plantain was regarded as food for the elite in the cities or food for birds in some villages, plantain products (chips, flour) are now flooding the streets, even in the dry non-plantain regions of Nigeria. Presently, unlike in the past few years, processing of plantain has turned out into a big business (Ngalani & Crouset, 1995; Akinyemi *et al.,* 2010). There are over 2000 small scale plantain chips processing business and several medium scale producers in the Lagos Metropolis alone (Akinyemi *et al.,* 2010). In the South Western part of Nigeria, several plantain flour processors are developing and the market seems to be expanding each day (Aiyelaagbe, 2001).

## 2.4. Cultivars of plantain

The number of plantain cultivars has been reported to vary from one country to another (Ogazi, 1996). Swennen (1990) observed that at least 116 plantain cultivars exist in different parts of West and Central Africa. In Nigeria alone, more than 20 cultivars have been reported, although only few are important commercially (Ogazi, 1996).

For production purpose, bunch type and plant size characteristics are used to differentiate between plantain cultivars (Ogazi 1996; Swennen, 1990). In general, the morphology of the bunch is used for classification. These include:

1. French Plantain: Inflorescence is complete at maturity. Many hands consisting of numerous rather small fingers followed by the bunch axis covered with neutral flowers and male flowers, the male bud is large and persistent (Ogazi, 1996; Swennen, 1990).

2. False Horn Plantain: Inflorescence is incomplete at maturity, hands consisting of large fingers followed by few hermaphrodite flowers (Ogazi, 1996; Swennen, 1990).

3. Horn Plantains: Inflorescence is incomplete, few hands consisting of few but very large fingers, no hermaphrodite flowers and no male inflorescence: inflorescence axis is terminated by a tail or a deformed glomerule (Ogazi, 1996; Swennen, 1990).

4. French Horn Plantain: Inflorescence is complete at maturity, hands consisting of large fingers followed by few hermaphrodite flowers (Ogazi, 1996).

The plant size depends on number of leaves produced before flowering:-

1. Giant: more than 38 foliage leaves;
2. Medium: between 32 and 38 foliage leaves;
3. Small: fewer than 32 foliage leaves.

When the plantains flower, leaf production has ended (Swennen, 1990).

### 2.5. Botany and growth habit of plantain and bananas

Plantains are tall, rhizomatous perennials. The short underground rhizome grows horizontally but slowly; aerial roots (suckers or followers) arise from lateral buds on the rhizome (Norman *et al.,* 1996). Within the AAA group, land races may attain a height of 4-9m and the Cavendish which was introduced from China in 1926 is widely cultivated because of its height of about 2m. The corm which is sometimes wrongly called a bulb is the true stem of the plant (Swennen, 1990).

The aerial shoots are pseudostems built of overlapping leaf bases rolled tightly around each other (Norman *et al.,* 1996). The pseudostem commonly has 11 unexpanded leaves of which more than half may be “non-functional” owing to wind damage, senescence and disease. When the pseudostem is 5.5- 10 months old and has produced 30-40 leaves (but up-to 50 leaves in sub tropical climates) the meristem becomes reproductive, no further leaves are initiated and leaves remaining within the pseudostem emerge at a slightly reduced rate

(Robinson, 1981). The number of leaves produced before flowering is not predetermined and can vary widely (Robinson, 1981); high temperature reduces number so that fewer leaves are recorded on plantains in tropical than in subtropical climates (Olsson *et al.*, 1984). The floral phase (Stover & Simmonds, 1987) from floral initiation to inflorescence (bunch) emergence from the throat of the pseudostem, is associated with inflorescence differentiation as the true stem elongates and the inflorescence is moving upwards from the pseudostem.(Stover & Simmonds, 1987).

Emergence of the bunch from the pseudostem is the start of Simmond's "fruiting phase". The fruit develops pathenocarpically from ovaries of the female flowers (Norman *et al.,* 1996).

The timing of development is difficult to generalize on because of perennation and the range of environments which plantains are grown. Cultivars take 6-8 months from sucker emergence to bunch emergence in Malaysia and 9-13 months from sucker emergence to bunch emergence in New Guinea (Ogazi, 1996). Stover and Simmonds (1987) cite data from Martinique of 6-7 months to bunch emergence at up-to 140m altitude, 9-10months at 365 m and 11-13 months at 400-640 m. Irrigation reduces the time to bunch emergence and the reduction is cumulative i.e. more pronounced in the second and third pseudostem growth cycles (ratoons) than in the primary cycle or plant crop. Most of the period to bunch emergence is associated with vegetative growth at latitude $29^0$ S in Australia cultivar. The period from bunch to floral emergence to harvest is about 100 to 120 (3-4 months) days in the tropics and as long as 220 days (7 months) in sub tropical Africa and Australia (Norman *et al.,* 1996).

**2.6. Climatic requirements**

The effect of climate on desert banana root and shoot growth has been demonstrated (Tuner & Lahav, 1983). Plantains and bananas are grown in the wet, wet and dry cool tropics (*Norman et al.,* 1996*).* The main determinant of their distribution is rainfall in excess of 1250 mm per annum (Stover & Simmonds, 1987). They are mostly grown in the lowland wet tropics, as seen from the distribution of cooking bananas within $7^0$ of the equator in Central and West Africa. However, they are sometimes very important in the wet and dry tropics, occupying more than 50% of the cropped land in Western Tanzania and being important cash crops under bimodal wet and dry water regimes in Garbon and Cote- d'Ivoire respectively (Stover & Simmonds, 1987).

Plantains are planted as rhizome pieces or aerial shoots at densities below 2000 per hectare. Growth of the primary crop is thus limited by radiation interception. Yield responds linearly to increasing populations to above 2,500 plants per hectare (Stover & Simmonds, 1989). However, by the time the bunch emerges from the pseudostem, the crop may have attained a reasonable leaf area because the second pseudostem (which later becomes the ratoon or second cycle crop) has a leaf area comparable to that of the main pseudostem. Crop leaf area index (LAI) at bunch emergence is 4-5 *(*Norman *et al.,* 1996). Leaves emerge at the rates of one per 6-15 days in the tropics (Turner & Barkus, 1980). Rate of leaf emergence is positively correlated with temperature, emergence ceases below $10^0$ C and production increases by one leaf per month per 3.3-.$37^0$ C rise in minimum or mean temperature from 10 to $20^0$ C or 13.5 to $25^0$C respectively (Robinson, 1981). Leaf spot (*Mycospherella Musicola*) low temperature or water deficit accelerate leaf senescence (Turner & Barkus, 1982).

The rhizome grows slowly in the first month but thereafter it constitutes 20-25 percent of whole plant dry weight until rhizome growth ceases at about the time the second pseudostom begins rapid growth. The shallow root of plantains makes the crop susceptible to lodging and water deficit (Olssson *et al.,* 1984; Swennen, 1990; Obiefuna, 1985). Lodging is a problem particularly in the Caribbean and West Africa, where losses due to high winds are regular and unavoidable. Stover & Simmonds (1987) estimated losses in Cameroon due to wind damage at 20% per annum. Good soil water conditions reduce susceptibility to wind damage by increasing pseudosterm thickness so that the proportion of broken pseudostem is reduced, as well as directly increasing fruit yield and the proportion of fruit which is harvestable (Obiefuna *et al.,* 2014). Conversely, drought or over wet soil increases wind damage, the first, presumably reducing the strength of the pseudostem and the second by increasing the amount of uprooting (Norman *et al.,* 1996).

Obiefuna (1983) reported that banana stems (underground rhizomes) exposed 12-22cm above the soil level were devoid of 50% of the potential roots system, resulting in poor yield and toppling by wind. Earthing up demands labour and is a repetitive process In addition, several roots could be damaged or injured in the process, making them vulnerable to soil borne pathogens and the plant susceptible to toppling (Obiefuna, 1983). .

According to Stover & Simmonds (1987), bunch weight often responds to increasing amounts or frequency of irrigation presumably because evaporation (and thus photosynthesis) is sensitive to available soil water. Plantain crop evaporation increases by 0.7mmper $^{0}$C rise in temperature (Turner & Barkus, 1982).

Environment affects timing of emergence and rate of individual fruit growth (Turner & Barkus, 1982). Late planting halfway through rather than at the start of the wet season may not delay the attainment of first flowering but it spreads the onset of flower emergence for the crop population. This causes a compounding delay in flowering in subsequent cycles On the other hand drought accelerates maturation and fruit quality. Fruit growth increases with temperature, being positively related to day degrees above 14.5 $^{0}$C (over the range 18-29$^{0}$ C) (Turner and Barkus. 1982) or to mean daily temperature from 13 to 22$^{0}$ C (Turner & Barkus. 1982). Stover & Simmonds (1987) found an optimum at 28-30$^{0}$ C which is perhaps the basis for agreement, at least among reviewers that the optimum temperature for plantain fruit yield is about 27$^{0}$C. Regular deep watering is an absolute necessity during warm weather. Standing water especially in cool weather will cause root rot (Green Earth, 2010).

In tropical rainforests, water limitation may prove to be a critical constraint to primary productivity due to climate change (Chaves *et al.,* 2002). Some of the responses of plants under field conditions occur at the leaf level in response to stimuli generated in the leaf itself or elsewhere in the plant. They have a negative influence on carbon assimilation and growth. However, it is the integrated response of the whole plant level including carbon assimilation and the allocation of assimilates to different plants parts and reproductive ability that eventually dictate survival and persistence under environmental stress (Pereira & Chaves, 1993). Bananas (*Musa spp*) rarely retain their full genetic potential for yield dueto limitations imposed by water. The banana plants sensitivity to moisture stress is reflected in changes in reduced growth through reduced stomatal conductance and leaf size (Kallarackal *et al.,* 1990; Turner 1995), increased leaf senescence (Batalgia, 1980), ultimately limiting the plants photosynthesis. Results on the effect of drought on plantain growth showed that drought stress in excess of 400m bars reduced pseudostem height and girth in all cultivars (Turner, 1995). The girth reduction and number of leaves added did not significantly differ in all cultivars used (Kallarackal *et al.,* 1990). Turner (1995) noted that banana pseudostem girth and leaf emission are sensitive to water deficits. Cultivar Gros Michel was reported to have intermediate reaction in relation to green leaf area loss (Haddad & Manzunilla, 1995). Cultivars Sukalinzi and French plantain “Gonga” (AAB) exhibited intermediate capacity. Hence water stress reduced pseudostem height, girth and loss in green leaf area (Haddad & Manzunilla, 1995). A reduction of assimilation rate of more than 50% was recorded in all cultivars with exception of French plantain (35.4%) by the end of 45 weeks. High ratio of leaf area in cultivars Lepcheng Kut and Nfuka under drought stress explained their high reduction in assimilation rate (Haddad & Manzunilla, 1995).

Drought, salinity and low temperature affect up take and conductance of water (Jain & Selvaraj, 1997). Musa genotypes have different inbuilt mechanisms for resistance to drought stress. Cultivars which indicated small reduction in gaseous exchange and leaf area loss and high leaf water retention capacity and assimilation rates showed more resistance to drought stress (Haddad & Manzunilla, 1995).

Plants' resistance to drought has been divided into escape, avoidance and tolerance strategies. Plants that escape drought exhibit high degree of developmental plasticity being able to complete their life cycle before physiological water deficits occur. Escape strategies rely on successful reproduction before the onset of severe stress. Plants can also endure stress condition by avoiding tissue dehydration, while maintaining tissue water potential as high as possible or by tolerating low water potential (Manuela *et al.*, 2003). Water loss is minimized by closing stomata and by reducing high absorbance through rolled leaves (Ehleringer & Cooper, 1992).

**2.7. Soil requirements**

Stover & Simmonds (1987) reported that the only factor common to the wide range of soils on which plantain are planted is good drainage. Good drainage is dependent on a favorable soil structure and pore size distribution and is essential to soil aeration. Alluvial soils used for plantain and banana production in Central Americas vary from stony sands to heavy clays, but all posses adequate pore space. However unaggregated compact clays and fine impermeable sands of Trinidad and Eastern Venezuela are unsuitable (Stover & Simmonds, 1987). Deep well drained loam and light clays loams were shown to give consistently high yields in Central America (Lahav & Turner 1983), and are probably ideal with respect to both physical and chemical properties (Stover & Simmonds, 1987).

The distribution of several hundred roots of plantain that rise from the plantain rhizome is affected by conditions in the soil profile, but they may penetrate to 1.5m (Lahav & Turner, 1983) and spread laterally for about 2-5m. In acid soils (Ultisols, Alfisols, Entisols and Incepitsols) in Puerto Rico, Irizarny, *et al.* (1981) found that all roots of plantain were above 30-60cm soil depth. According to Obiefuna *et al.* (2014), the plantain root distribution in response to different mulches showed significantly more plantain roots in top soil (0-15cm) than in sub soil (15-30cm). In plantains (Musa AAB), successive ratoons form progressively nearer the soil surface with the consequence that while shallow-planted parent crops may give good yields the ratoon crops yield around 30 percent less because of up-rooting by wind (Obiefuna, 1983).

Water tables also affect depth of rooting (Avilan *et al.,* 1982). Lysimeter studies with plantains in a clay loam soil showed that lowering the water table from 12 to 36cm increased yields of fruits from 5.6 to 37.8 t $ha^{-1}$ and increased root in the 15-30cm layer from 2200 to $4900mm^{-3}$ (Irizarny *et al.,*1980). For plantains, Irizary *et al.* (1981) reported the effect of soil texture on the distribution of cord roots, as a decrease in cord root length per $1000m^3$ of soil was observed in the heavier soils.

Sudden environmental changes bring about rapid and often transient changes in leaf elongation rate (Munns *et al.,* 2000). Such environmental changes include light intensity, soil water potential caused by changes in salinity (Cramer & Bowman, 1991) and/or humidity (Parish & Wolf, 1983; Shackel *et al.,* 1987). The speed of the response suggests that it is changes in leaf water status that drive the initial changes in elongation rate presumably mediated by changes in tugor (Munns *et al.,* 2000). Root rot from cold wet soils is by far the biggest killer of banana plant in temperate regions (Green Earth, 2010).

Uptake of nutrients by plantain is affected by site factors, temperature (Turner & Lahav, 1985), soil water and on the number, length and condition of the root system (CTA, 1987). When yields are heavy, uptake and removal of nutrients in harvested fruits is high. Only exceptionally fertile fields will retain high yields without fertilization (Norman *et al.,* 1996).

A good nutrient supply at an early stage is required to develop an effective leaf area index (LAI) which in turn promotes growth and bunch weight (Noman *et al.,* 1996). However, a good nutrient supply is required to accelerate development of secondary pseudostem and thereby increasing the rate of bunch production per hectare. Nitrogen is required in large quantities by plantain and together with potassium is the most commonly required fertilizer nutrient (Obiefuna, 1987).

Plantains are grown over a wide range of soil pH and tolerate acid pH values (5.0-6.5) (CTA, 1987) or as low as (Alvorez *et al.*, 1981). Low pH and low exchangeable calcium is often associated with the incidence of panama disease (Alvorez *et al.*, 1981).

## 2.8. Agronomy of plantain

### 2.8.1 Land preparation

On level land where the soil is deep and compact, ploughing is needed to improve aeration and water filtration whereas on sloping land minimum tillage is advised as well as contouring of rows to minimize erosion (Norman *et al.,* 1996). If perennial cultivation is considered, plantain should be planted through the mulch. Manual clearing is preferable to mechanical deforesetation as top soil disturbance greatly affects yield (Ogazi, 1996).

### 2.8.2 Planting date

Planting is done best at the end of the dry season and the beginning of the rainy season for adequate initial moisture and to avoid water logging of the young plants (Ogazi, 1996). In Puerto Rico, plantain is planted all year round because of their favorable climate. This enables sustainable supplies to their processing factories (Morton, 1987). However, in order to avoid surpluses and take advantage of the higher prices in winter and spring (February to April), planting dates have been manipulated to be in the first or second weeks of January, July, September, November and December (Morton, 1987). In Nigeria plantains are planted from March to April when the rains begin. Generally, bananas and plantains require 10 to 12 months from planting to harvest. However, late season (first week in August) orchard establishment has been advocated for increased yield with mulching orirrigation (Obiefuna, 1985).

In an experiment to determine the effect of monthly planting on productivity of plantain, Obiefuna (1986) reported that time of planting significantlyinfluenced plantain mat establishment, maturity and yield. Suckers planted in January and August had significantly better establishment rate than those planted in September or October because those plant lets from the later planting date attained only the $2^{nd}$ – $3^{rd}$ leaf stage and some of them did not have sufficient root system and nutrient reserves to survive the dry season (Ndubizu & Obiefuna, 1982). However, suckers taken from the orchard and planted in the dry season (November – March) were apparently preconditioned to the adverse weather while still attached to the mother plant. Thus suckers when severed and planted in December – February remained apparently dormant throughout the 10 weeks drought before sprouting during the next rains (Obiefuna, 1986). Although the leaf sheaths of these suckers were desiccated, the apical meristem remained active (Obiefuna, 1986) because the cells were completely submerged and protected in the rhizome (Ndubizu *et al.*, 1983) consequently, suckers planted in the dry season sprouted during the next rains with accelerated growth, resulting in early maturity, simulating the widely practiced dryseason planting for yams (Obiefuna, 1983).

Furthermore, the first ratoon crops of plantain established between November and February produced significantly (P=0.05) heavier and comparable bunch weights ($tha^{-1}$) than others. The results further indicated that the conflicting reports of plant crop yields being greater than, equal to or less than first ratoon crop yield or the generally reported low yield of plantain in West Africa could also stem from variations in time of planting (Obiefuna, 1986).

Emma-Okafor (2010) noted that days to 50% flowering in plantains were significantly influenced by manure rate and time of planting.

### 2.8.3 Planting materials

In the case of plantain and bananas, a sword sucker is the preferred planting material to ither planting materials (CTA, 1987). Plantain seeds are only used in breeding programs for propagation (Morton, 1987). Corms are customarily used for planting and Meixcan studies with “Giant Cavendish” have shown that those over 8kg in weight come into bearing early and in the first year, bunches are longer and heavier, with more hands than those produced from smaller corms. However, the disadvantage disappears from the second year. Most growers prefer “bits” 0.9-1.8kg sections of the corm. When corms are scarce, smaller sections (454-908g) have been utilized in Mexico and early fertilization applied to compensate for the smaller size. But in Queens land, it is specified that “bits” of “Dwarf Cavendish” shall not be less than 10.5 x 7.5x 7.5cm and “bits” of “lady finger” and other tall cultivars shall not be less than 12.5x12.5x9cm. They are usually fumigated by immersing in hot water for 20minutes at about 54.4$^0$C or in commercial nematode solution. Sometimes it is advised to apply fungicide to avoid spoilage. They are then placed away from all diseased thrash in the shade for 48hours before planting (Morton, 1987). In so much as “bits” are not often available, suckers are used but they should not be too young or too old. Just before suckers produce wide leaves resembling those of the mature plant but smaller, they have sufficient corm development to be transplanted. Sometimes suckers from old deteriorating corms have broad leaves from the onset which are called “water” suckers (Morton, 1987). These are unsubstantial with very little vigour, and are not desirable propagating materials. In India, banana and plantain trials in West Bengal showed that suckers from three to four months old with well developed rhizomes proved to be the best yielders. However, “bits” grow slowly at first but in two years time, catch up with plants grown from suckers. “Butts” (entire corms or rhizomes of mature plants) called “bull heads” in Wintward Islands are best used to fill vacancies in plantain for quick production, some farmers will use “butts” with several “sword suckers” attached to them. Very young suckers called “peepers” are utilized only for establishing nurseries (Morton 1987).

Diseases are often spread by vegetative propagation of plantains and bananas, and this fact has stimulated efforts to create disease free planting materials on large scale by tissue culture. Some commercial cultivars have been cultivated in Hawaii. A million “Giant Cavendish” bananas plants were produced by meristerm culture in Taiwan in 1983. In the field the plantlets showed 95 percent survival, grew faster than suckers in the first five months, had bigger stems and more healthy leaves (Morton, 1987). Commercial production of plantain demands good quality planting materials to save time and labour (Ndubuizu & Obiefuna, 1982).

In an experiment to determine the effect of different propagules and depth of planting on plantain productivity, Obiefuna, (1983) reported that at 9MAP, late sword suckers grew more significantly (93.1cm) than any other propagation material. Girth of late sword suckers was significantly greater than that of maidens, early sword suckers, bits and peepers. Furthermore, in late sword suckers, rhizome food reserve was presumably adequate during the dryseason. The stools that died through the dry season regenerated through their rhizomes when the rain resumed (Obiefuna, 1983). Suckers will elaborate 0.4 more feed, thus ensure quick canopy cover, reduced weed competition and adequate moisture conservation. Late sword suckers also retained significantly more leaves during the dry season (Obiefuna, 1983). The bunch weight of first ratoon established from sword suckers was significantly ($P<0.05$) higher than those from bits and peepers (Obiefuna, 1983).

Bakheit *et al.* (2003) had observed differences in time to corm germination with different planting materials.

### 2.8.4 Plant spacing

Plant spacing varies with the ultimate size of the cultivar, soil fertility and other factors. Close planting protects plantations exposed to high winds, but results in fewer suckers, hinders disease control, and has been found to be profitable for only the first year. In subsequent years, fruits are shorter, the flesh is softer, and bunches ripen prematurely (Morton, 1987). The standard planting is 1,235 plants/ha. Increasing to 1,976 plants/ha has increased yield by 4tons in Puerto Rico but elevating density to 3,212/ha has not shown any further increase (Morton, 1987). In Surinam, most of the plantains are grown at density of 2000-2,500/ha, but density may range from 600-4,400/ha. In general recommended spacing according to Ogazi (1996) is 3m x 2m which gives a plant density of 1667 plants, but with a spacing of 2.5m x 2.5m, density is 1,600 plants (Obiefuna, 1990; Swennen, 1990).

The roots of plantains and bananas may extend outward 5.5m. The higher the altitude, the lower the density.This must be because of solar radiation which is reduced. Too much space between plants allows excessive evaporation from uncovered soil and increases the weed problem. Growers must determine the most economical balance between sufficient light for good yields and efficient land management. Spacing distances of “dwarf Cavendish” ranges from 3mx1.5m to 4.5x3.6m (Morton, 1987). A spacing of 3.6m between rows and 2.4m between plants allows 450 plants per acre or 1,112 plant/ha. Hexagonal spacing gives the maximum number of plants per area. Double and triple row plants provide alleys for mechanical operation and harvesting (Ogazi, 1996; Morton, 1987).

### 2.8.5 Depth of planting holes

Planting holes should be at least 45cm wide and 38cm deep but may be as much as 0.91m wide and 0.6m deep (Morton, 1987). On hill sides suckers are set with the cut surface facing downhill; the bud or eye of a bit must point uphill; so that the follower sucker will emerge on the uphill side where the soil is deepest. A surface cover of about 4-10cm soil is trampled down firmly. According to CTA (1987) and Obiefuna (1983) standard planting holes is 60x60x60cm, while Swennen (1990) recommended 30x30x30cm.

Obiefuna (1983) reported that deep planting appeared to stimulate greater suckering in all planting materials (peepers, bits, maidens, early and late sword suckers), especially late sword suckers. The technique of hilling for increased suckering is apparently the reverse of deep planting (Obiefuna, 1983). Deep planting (30cm) also increased yields of the first ratoon crops of peepers and early sword suckers but had little effect on bunch weight derived from other propagules (Obiefuna, 1983). Uprooting in shallow plantings could be as a result of poor rooting system as the rhizome becomes exposedresulting from top-soil erosion or soil wash caused by water running down the pseudostem (Obiefuna, 1983). The situation is evident because of the combination of heavy rainfall and sandy soil, characterizing the plantain growing rainforest region. The productive stands are thus progressively reduced, resulting in the decline in yield of such orchards, (Obiefuna, 1983).

In Kassala region of Sudan, banana plants are usually planted at a depth of 30-40cm, a high proportion of the banana plantation become uneconomic after the third ratoon crop (INIBAP, 2004). Shallow planting was associated with smaller bunches (Obiefuna, 1983; Fraser & Eckstein, 1998). Backeit & Elbadri (2004) reported that planting plantains at deeper trenches of 60x60x60cm seemed to hasten flowering and increase bunch weight while shallower trenches of 60x60x40cm and 60x60x50cm seemed to delay flowering and reduce bunch weight except in first ratoon crops where as maturation seems to be controlled by temperature (Robinson,1981). Bakhiet & Elbadri, (2004) reported that non significant effect of planting depth on sucker production in plantain may be due to using uniform sword sucker planting materials.

### 2.8.6 Weed management

Weed control is essential. According to Morton (1987), gueese are installed as weeders in plantain plots in Puerto Rico. However they consume mostly grass and fail to eliminate certain broad-leaved weeds which still require clearing out. Certain herbicides including Diuron and Ametryne have been approved for plantain fields (Morton, 1987). They are applied immediate after planting but great care must be taken to minimize adverse effects on the crop. Ametryne has been no shown to be relatively safe for the plants and it has a short life in the root. The presence of weeds such as *Cyperus rotundus* L. (yellow nutgrass, purple nutsedge), loqui (coyollo) decreases yield and compete with the crops for nitrogen (Morton, 1987).

In some plantations, dry leaves of banana or plantain are used as much to control weeds. Some growers tend to leave ground cover such as *Glycine javanica, Commelina species* and other climbers which tend to climb the plantain stems and become a nuisance. Sometimes, short term crops are interplanted in young plantain fields for example egg plant, maize, peppers, tomatoes, okra, sweet potatoes, pineapples or upland rice (Ndubuizu, 1983). A space of at least 0.91m must be kept clear around each plantain plant. However, the floral and the reproductive phases are the most sensitive to any form of stress particular weed competition (Ndubuizu, 1983).

Alagba *et al.* (2014) reported that poultry manure application to plantain in both mono and mixed kola/plantain plots effectively controlled weeds in comparison to those in unmulched plots. Anderson (1996) reported that weeds in plantain can be controlled through mulching use of herbicides and manually while Obiefuna (1989) reported that it is feasible to control weeds in plantain biologically using egusi melon. Swennen (1990) found mulching the most efficient weed control technique in plantain because a mulch layer impedes or impairs weed growth.

According to Gbadegesin (2013), organic systems tend to support a greater density, species number and diversity of weeds compared to conventional management. In West Africa, weed growth is very prolific and lack of effective weed control is a key factor that reduces yield and this leads to overall yield decline (Shaibu *et al.,* 2012).

### 2.8.7 Fertilizer application

Plantains and bananas are heavy feeders (Morton, 1987). In general, it can be said that plantains and bananas have high nitrogen and phosphorus requirements and a fertilizer formula of NPK 8:10:8 is usually suitable and normally 1 to 1½ tons/ha may be required (Morton, 1987). One third of the fertilizer is worked into each planting site when most of the plants appear above the ground, one third in a circle about 30cm from each plant 2 months later and one third at double the distance 2 months after that. However, fertilizer needs will depend on deficiency signs (often determined) by leaf analyses as the plantation develops (Morton, 1987). In Nigeria according to Obiefuna (1987), productivity of plantains intercropped with cassava, cocoyam and yam, fertilized with 0, 320, and 480kg N/ha showed that yields from nitrogen fertilized intercrops were higher than those unfertilized treatments. In plantain+cassava intercrop receiving 480kg N/ha, plantain growth was suppressed. Plantain intercropped with yam and fertilized with 320kg N/ha matured early and produced better bunches than other treatments. Plantains + yam or cocoyam intercropping systems were recommended because of improved plantain establishment and increased combined crop yield. However intercropping plantains with cassava, cocoyam, or yams without fertilization resulted in significantly less plantain growth and establishment. However, in plantain+cassava intercrops fertilizer application beyond 320kg N/ha drastically reduced plantain establishment (Obefuna, 1987) while in yam and cocoyam intercrops most of the plantain established well even with higher nitrogen. However for each intercrop, there was no difference in bunch weight for plants receiving 320 or 480 kg N/ha, 320kg N/ha consistently produced the maximum total crop yield for each intercrop (Obiefuna, 1987).

In Nigeria plantains are usually planted around homes and usually supplied with house hold perishable wastes which act as organic manure (Swennen, 1990; Ogazi, 1996). However the high productivity of plantain under such small holder compound production system is attributed to such household wastes including livestock waste, waste water and wood ash thrown around the plantain mats (Onwuzu & Nweke 1983; Baiyeri *et al*., 2004; Robinson, 1996). According to Obiefuna (1990), the application of differently treated manures affected marked growth and yield variations in plantains. Plantains which received poultry farm yard manures established significantly (P=0.05) better than either refuse compost, cattle farm yard manure or the control which had the least surviving plantain. However plantains which received poultry and cattle farm yard manures proliferated significantly more suckers than the control or where refuse compost was used. Plantains manured with poultry farm yard manure matured early and produced similar plantain bunches which were significantly superior to those which received refuse compost. However, plantains which had cattle farm yard manure developed significantly heavier bunches than these which received only refuse compost. Yields of the first and second ratoon crops significantly increased where poultry and cattle farm yard manure were applied. Only very few plantains were infested with weevils when poultry farm yard manure were applied without furadan or wood ash dressing (Obiefuna, 1990).

N, P, K, fertilization has been found to improve plantain growth and yield. Plantains have been found to require about 20g N/plant in 3-4split application with a basal dressing of 200g plant each of $K_20$ and $P_20$ for optimum yield (Obiefuna *et al.*, 1983). Plantain has highest demand of potassium during flowering. Required dosage of potassium ranges from 250-600kg/ha. If the application is done 2-3months to flowering, during the 18-19$^{th}$ leaf stage, it provides adequate supply during transitional 24th leaf stage. Adequate dosage of 300gk$_2$O/plant gave highest yield of plantain, and yields were depressed at rates higher than that. Addition of 50-100 kg/ha Mg has been shown to increase yields (Obiefuna, 1984). Subject to soil test, fertilizer at the rate of 250-300kg/ha N, 30-60kg $P_20_5$, 550-625kg $K_20$ and 120kg Mg/ha is considered adequate for optimum growth (Irizary *et al.*, 1981).

**2.8.8 Disease and pest control**

Black Sigatoka leaf spot is the major disease attacking plantains, nematodes and stem borers are the major pests (Swennen, 1990). Damage by plantain weevil pests (*Compolistes sordidus*) and root knot lesions by nematodes (*Heliotylenchus multilntus incognita*) also contribute to rapid yield decline in compound plantains (Braide & Wilson, 1982; Ogazi, 1996). Furadan (Morton, 1987), chlordecone, isoferphose and aldicarbe (Ogazi, 1996) are used and stem borers can be controlled by leaving the land under fallow or application of coffee husks (Ogazi, 1996; Swennen, 1990). Most small holder plantain farmers who lack funds to purchase or procure modern inputs of fertilizers and chemicals only apply organic manures (Obiefuna, 1990).

Black Sigatoka caused by the fungus *Mycospherella fijiensis* reduces yields in sub-Saharan Africa up to 30-50% (Obiefuna, 1987; Swennen, 1990) and can be controlled by a disease resistant cultivar developed by IITA (Ogazi 1996; Swennen, 1990). The disease can be controlled with aerial application of fungicides belonging to the groups of benomyl, benzimidazoles, chlorothalonils, etc and soil applied fungicides such as triadimefon and triadimenol (Swennen, 1990; Ogazi 1996). Intercropping plantain with fast growing dense canopied cassava TMS 30572 also reduced black Sigatoka disease incidence and severity in plantain at establishment stage. (Emebiri & Obiefuna, 1992). Stem borers bore channels in the corm, plants become weak, especially during the dry season, and tip over, leading to drastic yield decline (Swennen, 1990).

Alagba *et al.*(2014) reported that application of poultry manure at 10- 20 t $ha^{-1}$ significantly ($P<0.05$) reduced the severity of black Sigatoka leaf spot disease and kola blight disease in both sole plantain and intercropped kola/plantain plots. Emma-Okafor (2010) also corroborated this report and noted that poultry manure application drastically reduced pest damage in late season plantain in comparison to unmanured plots.

**2.8.9 Mulching**

A mulch is a layer or protective cover of material either organic or in organic applied to the surface of an area of soil (Wikipedia, 2013) to conserve moisture, improve the fertility and health of the soil, reduce weed growth, reduce soil temperature fluctuation and enhance the visual appeal of the area (Staufer,, 2012; Wikipedia, 2013; Whiting *et al.*, 2011) reduce soil compaction, improve soil structure, (Umass Extension, 2012) and add organic matter to the soil (Clatterbuck, 2010). Application of mulch is one of the most effective ways to conserve moisture during dry periods (Umass Extension, 2012). Mulching is an underutilized practice that should be considered by all serious gardeners, whether they grow fruit crops or not and has many benefits some of which cannot be duplicated by any other horticultural practice (Umass Extension, 2012).

Staufer (2012) reported that for arable soils, the most effective conservation practices are those that provide some degree of surface cover of the soil, while Clatterbuck (2010) noted that besides keeping the moisture in the soil, mulches can also reduce soil temperature, increases soil life, infilterability and water retention.In order to maximize the benefits of mulch mulching should be done when soil temperature have risen sufficiently but soil moisture content is still relatively high (Wikipedia, 2006).

#### 2.8.9.1. Types of mulch

Mulch materials are of different types and may be organic or inorganic materials. Organic mulches include hay, wood chips, ground bark, saw dust, leaves, grass clippings, pine needles (Umass Extension, 2014), kitchen scraps, shells, wool, animal manure (Wikipedia, 2013), palm bunch residues (Obiefuna *et al.*, 2014), cocobean hulls, peatmoss, mushroom compost, (Williams, 1997), etc.

Inorganic mulch materials include landscape fabric (geotextile) and plastic film (Clatterbuck, 2010) that are primarily used for weed control and to retain soil moisture. Plastic mulch is often used in vegetable production, newspaper and other paper products can be used but the heavy metal content in many inks may make this choice less desirable (Umass Extension, 2012). Plastic mulch used in large scale commercial production is laid down with a tractor-drawn or stand alone layer of plastic mulch (Wikipedia, 2012). This is usually part of a sophisticated mulchamical process, where raised beds are formed, plastic is rolled out on top, and seedlings are transplanted through it. Drip irrigation is often required with drip tape laid under the plastic, as plastic mulch is impermeable to water (Wikipedia, 2013), and therefore prevent soil evaporation and water losses and erosion via the soil surface (Staufer, 2012). They also aid in the even distribution of moisture to the soil which reduces plant stress prevent sunlight from reaching the soil which can limit most annual and perennial weeds. The prevented evaporation also has a supplementary effect, it avoids rise of water containing salt, acts as a barrier to soil pathogens and especially opaque plastic mulches prevent germination of annual weed seeds from receiving light (Wikipedia, 2013).

Plastic mulches have been used to measure productivity (Staufer, 2012). However, they are completely impermeable and therefore prevent soil evaporation and limit water losses and erosion via the soil surface.

#### 2.8.9.2 Effect of mulching on plantain productivity

Wikipedia (2013) reported that wood residues should be utilized for humus maintenance wherever it is economically feasible to do so. Furthermore, saw dust reacts mulch as chips, shavings, and bark, except that decomposition is more rapid in more finely divided material. Saw dust and wood shavings have been reported to improve structure and aeration in heavy soils (Staufer, 2012), increase water absorption and infilteration and conserve moisture through reduced evaporation and weed control (Clatterbuck, 2010). Obiefuna (1986) advocated for the use of saw dust as mulch in plantain because of its availability, cheapness, sufficiency and slow rate of decomposition.

Obiefuna (1991) reported over 60% yield increase in plantains mulched with wood chips, saw dust and palm bunch refuse (Obiefuna *et al.,* 2014). Soil covers are beneficial to plantain because of their capacity to conserve moisture and make the moisture available over a longer period (Bhattachraya & Rao-Madhava, 1985). IITA (1981) reported yield increase of about 400% in mulched plantain over that of unmulched fertilized plots over a 4 year period. Obiefuna (1987) and Wilson (1987) noted that heaviest bunches and highest number of hands and marketable fingers were obtained in saw dust mulched plots. Obiefuna *et al.* (2014) and Obiefuna (1985) reported that mulching enhances growth and increases bunch yield in both first and second year crops in plantain.

The choice of mulch materials is usually determined by local availability at the time of mulching a specific crop (Obiefuna *et al.,* 2014). Although many sources of mulch are in the ecozone around hedges, trees and fallows, alley systems, waste from mills, factories and urban areas etc, crop residues and weeds are the most economic mulch materials. They are most abundant at all times of the year (Obiefuna *et al.*, 2014). The effect of mulching in promoting plantain growth and yield may not be limited to moisture conservation since even at the peak of the rains mulching still executed significant influence on growth and yield of plantain (Obiefuna, 1985). Furthermore, availability of mulch could limit the use of irrigation in plantains (Obiefuna, 1985). According to Swennen (1990), suitable mulch materials for plantain could be obtained from elephant grass (*Pennisetum purperum*), which is rich in potassium, cassava peeling, wood shaving, palm bunch refuse, dried weeds, kitchen refuse and trees which are slashed when the field is cleared.

Strong influences of the edaphic conditions on *Musa spp* growth and production have been reported (Blomme *et al.,* 2005). For example the application of mulch in desert banana plantation improves crop nutrient availability and soil physical properties and results in an improved root growth and subsequent yield increase (Wilson *et al.,* 1987). Nutrients move to plant roots by mass (bulk) flow and diffusion. In addition, as roots grow through the soil, they come in direct contact with and intercept nutrients associated with soil particles that are displaced by roots (Adler *et al.,* 2012). The quantity of nutrients absorbed by plant roots through root interception depends on the soil volume occupied by the roots, the concentration of nutrients in the soil, and the root morphology (Adler *et al.,* 2012). The resulting concentration gradient that forms from the bulk soil to the root surface causes nutrients to diffuse along that gradient towards the root surface. Conversely, elements delivered to the root surface in excess of plant demand establish a concentration gradient away from the root surface and diffusion is then away from the plant root (Adler *et al.,* 2012).

Organic matter has been reported to effectively reduce the incidence and severity of some diseases and pests of plantain. When poultry manure is used as mulch, it has repellent reaction which tends to ward off pest damage. This report is corroborated by Obiefuna (1990) who reported that manuring with a combination of poultry manure, wood ash and household waste not only improved establishment and yield of plantain but reduced infestation by borer weevils and nematode. Low disease incidence of black Sigatoka leaf spot disease has been reported by Alagba *et al.* (2014) with the use of increasing rates poultry manure mulch, with lowest incidence recorded at the rate of 10tha$^{-1}$. Banful *et al.* (2000) reported that mulching plantains with prunnings of *F.macrophylla* effectively reduced population of *Heliotylenchus spp, Pratylenclus spp* and *Meloydogyne spp*.

Plantains have three distinct growth phases; pre-floral, floral initiation and reproductive phases (Ndubuizu *et al*., 1983). Each growth phase responds differently to a given stress in time, magnitude and space. The floral and reproductive phases are the most sensitive to any form of stress particularly drought. Although late season orchard establishment (1$^{st}$ week in August) of plantain has been advocated for increased yield (Obiefuna, 1985), the need for increased survival rate of plantain through mulching or irrigation during the subsequent dry season was also emphasized. The vegetative (pre floral) growth phase in plantain tolerates severe moisture stem without notable yield reduction (Obiefuna, 1985). Availability of adequate quantities of mulch could limit the use of irrigation in plantain production (Obiefuna, 1987).

Beneficial effects of mulching in plantain production have been attributed mainly to increased soil organic matter (Obiefuna, 1987; Swennen & Wilson, 1983). Although soil temperature has been mentioned as a factor in yield decline in plantain (Braide & Wilson, 1980), its effect has not been investigated. Daily soil temperature exceeding 30$^0$C at 5cm dept are common during the growing season at different agroecological regions of the tropics (Maurya & Lal, 1981). Mulching and organic manure plantain production system is the advocated remedy for plantain yield variation. Mulching plantain at the onset of the dry season is common (Obiefuna *et al.,* 2014).

In a study on the effect of five different mulches on plantain, Salau *et al.* (1992) reported that organic mulches (elephant grass and wood shavings) maintained more favourable physical and chemical soil properties than synthetic (plastic) mulch or unmulched treatments. At 5cm depth the mean monthly maximum soil temperature was lowest under wood shavings and the soil water infilterability was highest under wood shaving mulch. Furthermore, mulching significantly enhanced vegetative growth and increased bunch yield in both first and second year crops. Increase in total yield (plant and first ratoon crops) was on average about 41% higher with mulched treatments than with control (unmulched).

In an experiment to determine the effect of mulching and fertilizer on intercropped plantain and cocoyam, Shiyam *et al.* (2010) reported that the bunch and cormel yields of plantains and cocoyam were significantly (P=0.05) influenced by saw dust mulch and fertilizer with saw dust to NPK at 150kg /ha producing the highest bunch and cormel yields and hence the highest total productivity and aggregate yield. Mulched plots substantially out-yielded those in un-mulched plots at each rate of fertilizer applied possibly due to improvements in soil physico-chemical and biotic conditions. While the yield decline in control and non-mulched plots (fertilized) may have been a direct response to soil fertility decline. Furthermore, slowly decomposing saw dust protected the soil surface and created favourable soil conditions and enhanced the development of the cormels/corms. Banful *et al.* (2000) reported that mulching plantain with prunnings of *Flemingia macrophylla* resulted in significantly (P<0.05) higher retention of soil moisture and lower soil temperatures than *Leucaena leucocephala*. Furthermore, growth of plantain determined by plant height, leaf production, pseudostem girth and yield were significantly greater in *F.Macrophyalla* mulched plots than *L.leucocephala* treatments and control plots where no mulch was introduced.

#### 2.8.9.3 Effect of mulching on soil biota

Mulching has been reported to encourage population of soil biota. Obiefuna *et al.* (2014) reported that organic mulches stimulated rapid multiplication and activities of the soil improving bio fertility indicators (bioindicators) and ecosystem engineers essentially snails, earth worms, millipedes and termites. These biofertility indicators, in favourable environmental factors, quicken mulch decay, mineralization cycle and nutrient availability to plantain (Alagba *et al.,* 2013; Obiefuna, *et al.,* 2014).

The rate of decomposition of organic mulch is determined by its net composition and reaction to environmental factors of water, temperature, micro and macro soil inhabitants (Wikipedia, 2013). The activity of soil organism follows a seasonal, as well as a daily pattern. Not all organisms are active at a particular time. Even during periods of high activity, only a fraction of the macro fauna are busy eating, respiring and altering their environment (Chikezie *et al.,* 2008). The macro fauna group comprises those soil animals that are more than 1cm long or have a width or diameter of more than 2mm (Moriera *et al.,* 2008). The most significant group are earthworms, termites, ants and beetles. The earthworms probably are the most important soil invertebrates in temperate regions but in the tropics, their role is taken over by beetles and termites (Moriera *et al.,* 2008). The macro fauna play an important role in soil ecosystem as soil engineers, especially in the tropics, significantly influencing the physical and chemical properties of the soils they inhabit especially by the creation of macropores and transformation and redistribution of organic matter. Macro faunal groups are often used (or proposed) as indicators of soil biological quality and therefore form an important component of the soil biota, indicative of overall soil biodiversity and effects of land use change and management practices. This is because of their important role in ecosystem processes and their sensitivity to environmental conditions. Furthermore, because of their relatively high biomass, they form an important constituent of the food web in the soil (Moriera *et al.,* 2008).

Most earth worms are denoted ecosystem engineers (Lavelle *et al.,* 1997), because they are active in mixing and digging the soil, modifying the hydraulic and chemical properties. The climatic parameters for earthworms include soil temperature, soil moisture, humidity and rainfall (Chikezie *et al.,* 2008). Highest rainfall (October – November) correlated with highest earthworm population in October – November and highest soil moisture content (Kale & Kermegam, 2010). High surface temperature and dry soils are limiting factors to earthworm than low temperature and water logged soils (Kale & Kermegam, 2010).

In tropical and subtropical countries, but also in some northern parts of the world, termites belonging to the insects order Isoptera are the most voracious of wood destroying insects. Not all termites in tropical countries play an important role in the soil fertility (Moriera *et al.,* 2008). Dead wood is the most preferred food for termites and most species of wood are susceptible to termites. A number of tree species and few non tropical trees do have a natural chemical resistance of their heart wood to termites and other insects (Becker, 2003). Defence is especially and typically achieved by secreting anti-feedants (such as oils, resins and lignin) into their woody cells. This reduces the ability of termites to effectively digest the cellulose (Wikipedia, 2012). Individual termite nests from tropical rainforests are formed in colonies which maintain the ability to remain self sustaining for very long periods without regular precipitations or water replenishment. Lignin, although indigestible in most species is used to reinforce waste materials and shelter tubes (Wikipedia, 2013). Termites are responsible for the removal of up to 100% herbaceous matter (Wikipedia, 2012). Because of the large number of termites in a colony, timber, leaf or other preferred food, once under attack may be quite rapidly destroyed (Becker, 2003). Termites clear away leaf and woody liter and so reduce the severity of the annual fires in African savannah (Mommer, 2013). Soils surrounding termite mounds or nests also have a massive increase in fertility due to higher nutrients status of the materials eroded from mound surfaces (Mommer, 2013).

Millipedes are attracted to dark, cool environments (USAF, 1991), and usually unnoticed in the summer due to their nocturnal habits and tendency to disperse (NEARLS, 2012). They feed on living and decomposing vegetation and occasionally on dead snails, earthworms and insects (NEARLS, 2012). They cannot tolerate water-saturated soils which forces them to the surface and higher ground. Likewise drought conditions can stimulate migration (USAF, 1991). They are usually abundant in compost piles and heavily mulched gardens and require moist habitats of high relative humidity.Snails are cold blooded animals and are therefore sensitive to atmospheric humidity and temperature (NEARLS, 2012). They prefer a habitat that is neither too hot nor too cold. When the temperature is too hot or too cold, they withdraw into their shell and aestivate (NEARLS, 2012; Nwachukwu, 2013). They thrive best in temperatures between 10-23$^0$C (Nwachukwu, 2013). Dry season in Nigeria, particularly the hamattan is not favourable for snails (Nwachukwu, 2013).

Crickets which are cold blooded omnivorous scavengers, feed on organic decaying plant materials, fungi, and some seedling plants (Wikipedia, 2012).

**2.8.9.4 Decomposition of mulch**

Organic mulches decay over time, and are temporary, the way a particular organic mulch decomposes and reacts to wetting by rain and dew affects its usefulness. The effect of decomposing plant materials on the uptake of nitrogen by crops under field conditions are apparently mulch dependant. Decomposing legume stubble has been reported to release nitrogen and stimulate plant uptake (Clatterbuck, 2010).

Organic mulches vary in their carbon: nitrogen (C:N) ratio (Obiefuna *et al.,* 2014). The high C:N ratio of saw dust and wood shavings makes these mulches difficult to degrade by termites and microbes, making them stay longer in the soil (Whiting *et al.,* 2011). Wood chips may take as long as 10 years to decompose (Whiting *et al.,* 2011).

According to Obiefuna (1987) leaf production of the plantain crop under different mulch materials decreased as the dry season progressed from December to March. Plantain mulched with grass maintained a good rate of leaf production up to January and thereafter leaf production dropped drastically as in the unmulched plantain. However, as the rains stabilized leaf proliferation was faster in plantains mulched with grass than the unmulched plantains though at a significantly slower rate than those mulched with either sawdust or wood shaving. The use of grass mulch material, though adequate early in the dry season could not withstand prolonged dry season in excess of two months. The exposure of plantains to supra-optimal soil temperature retarded growth and subsequent yield and may therefore be considered critical in plantain survival during crop establishment. The poor protection offered by trash mulch probably emanated from rapid breakdown of the grass mulch by termites. Mulched plantains were significantly superior to the unmulched ones with respect to the growth, yield and yield components. Mulching increased yield and the number of suckers per mat, and reduced wind damaged among the ratoon crops e.g. yield in the first ratoon plantain increased by 12.6% and 12.8% over the plant crop when mulched with sawdust or wood shavings respectively. The yield of the first ratoon crop increased by 70.3%, 43.2% and 27.0% respectively for sawdust, wood shavings and grass over control (Obiefuna, 1987).

Earliness in sucker development following suppression of apical dominance due to rapid growth (Swennen, 1990) in mulched plantain accelerated the rate of ratooning. With plantain, the number of suckers emitted varies considerably according to the cultivar (from 1 to more than 10). The growth of these suckers is greatly influenced by the stage of growth reached by the parent plant (eg. flowering, harvesting), and operations undertaken by the grower (eg. desuckering) (CTA, 1987). The effect of mulch in promoting plantain growth and yield may not be limited only to moistureconservation since even at peack of the rains mulching still executed significant influence on growth yield of plantain (Obiefuna, 1985).

In another experimenton the effect of mulching and increasing level of fertilizer on false horn plantain (Musa AAB), Obiefuna (1989) reported that fertilized and mulched plantain not only proliferated leaves faster but also enhanced the leaf longevity by 2-3 weeks over plantains which were fertilized but not mulched and about 5 weeks over control.Furthermore even without fertilizer sawdust mulch significantly (P=0.05) stimulated early sucker formation barely 4-5 months after planting thus generating more suckers permat at harvest. Increasing nitrogen levels however inhibited early sucker emergence by 2-3 months (Obiefuna, 1989).

Increased yields following use of saw dust mulch in straw berries was due to the fact that after decomposition proceeded for several years, the resulting increase in humus-like organic matter gave the soil an improved porous sponge structure, greater usable moisture capacity and better aeration (Clatterbuck, 2010).

**2.8.10 Desuckering**

Plantain suckers grow very slowly. After harvest, all suckers start to grow at the same time and most have to be eliminated to reduce competition (Swennen, 1990). The tallest is left to guarantee the follow-up and maintain the density.Thinning usually has to be repeated a month later as new suckers will have emerged by that time (Ogazi, 1996; CTA, 1987). Suckers are thinned with machetes. The sucker pseudostem is cut off near its corm and the point of the machete is twisted in the growing tip, thus killing it (CTA, 1987). Delayed flowering in plantains has been attributed to multiple suckers (Swennen, 1990).

**2.8.11 Plantain harvest and bunch weight**

The stage at which plantains bunches are cut at harvest depends on the cultivar, the grower and the intended use of the bunches (own consumption, sale on local market or export) (CTA, 1987). However Swennen (1990) and Obiefuna, (1987) reported that the plantain bunch is harvested 3-4 months from flowering (Shooting). Growth in Musa plant has been reported to be significantly correlated to yield (Baiyeri & Mbah, 1994; Stover & Simmonds, 1987; Baiyeri *et al.,* 2000). Shaibu *et al.* (2012) noted that plantain bunch weight was significantly and positively correlated with all yield components. Further to this, number of hands, number of figers, fruit weight, fruit length and fruit filling are all major contributing factors to yield

(Ndubuizu *et al*., 1983; Shaibu *et al*., 2012). In plantain and banana, weight of a bunch is determined by the total number of hands and fingers produced per bunch, therefore the weight in kilograms is a function of the total number of hands and fingers (Shaibu *et al*., 2012) and weight of the fingers (Ndubuizu *et al*., 1983).

### 2.8.12 ControIling high mat

After production of several ratoon crops, the upper surface of corms in aging plantain fields can be seen above the ground surface. This phenomenon called high mat is believed to have several causes (Ogazi, 1996). The nature of ratooning in plantain seems tobe particularly important (Swennen, 1990). High mat exposes the roots which dry out. The plants become weak and tip over easily because they are no longer firmly based in the soil.Earthing up (adding soil around the plant) does not help much (Swennen, 1990; Ogazi 1996). However mulch protects the roots which would otherwise dry out. Mulch also improves ramification and stability of the plant (Ogazi, 1996; CTA, 1987; Swennen, 1990).

## 2.9 Influence of organic manure on crop production

Modern agriculture, based on monoculture of cash crop varieties that require high input depends on heavy application of inorganic fertilizers and on chemical pesticides for pest control (Sun & Hsieh, 1992). The sustainability of modern agriculture has become a subject of great concern to policy makers, researchers, and farmers world wide (Acquaah, 2002). Organic agriculture involves crop production using little or no chemical Acquaah (2002). The process has gained popularity as society moves towards healthy eating and environmental protection. The fundamental difference between organic and conventional farming systems is in the ways in which plants receive their nutrients and protection from pests and diseases during cultivation (Acquaah, 2002). Nutrient recycling is the organic way of fertilizing crops while inorganic involves high external inputs.

Agricultural development and production is sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate, humane and based on a holistic scientific approach. This means that sustainable agriculture and rural development including forestry and fisheries must meet the nutritional requirements and other human needs of present and future generations, provide durable and decent employment, maintain and, where possible enhance the productivity and regenerative capacity of the natural resource base, reduce vulnerability and strengthen self reliance (USDA, 2007). Furthermore, it encompasses a range of strategies for addressing a number of problems including loss of soil productivity from erosion and related nutrient losses, the pollution of surface water and fertilizers, and low farm incomes as a result of reduced commodity prices and high production costs (Hsieh & Hsieh, 1989). The environmental factors for production are the same in organic and inorganic farming (Acquaah, 2002).

The maintenance of soil organic matter levels and optimization of nutrient cycling are fundamental to the sustained productivity of agricultural systems (Mullonggy & Merckx, 1991). Healthy soil is the foundation of the food system, it produces healthy crops that in turn nourish people. Therefore maintaining a healthy soil demands care and effort from farmers (FAO, 2005). Organic matter exerts a profound influence on crop nutrition, soil structure and cultivation (Adams & Early, 2005). It is simultaneously a source and a sink for nutrient elements which can form organic moieties. It has physical and chemical properties which facilitate aggregation with mineral particles, particularly clays, and in turn modify soil physical structure and influence soil water regimes; it is a source of energy for the soil biota, and thus influences many of the biological mediated processes of soil (Mullongy & Merckx, 1991; FAO, 2005).

### 2.9.1. Index of soil fertility

The organic matter content of the soil is often used as an index of soil fertility (Hsieh & Hsieh, 1989). Generally, organic matter enhances the soil in three ways by altering the physical, the chemical and the biological properties (Sun & Hsieh, 1992). The term "soil organic matter" covers all plant and animal tissues in the soil. Soil organic matter may form to humus and become an active component of the soil (Acquaah, 2002). The application rate of organic matter therefore is determined by soil fertility, the nutrient content of the organic material concerned and the nutrient requirements of the crop. However Sun & Hsieh (1992) stated that less than 2% organic matter in the soil is generally counted to be "*insufficient*", 2-5% is "*fair*" and more than 5% is "*plenty*".

Since the nutrient content of the organic fertilizers varies greatly according to the type of organic material while the nutrient requirement of different crops also vary, the type of organic fertilizer should be selected to meet the requirement of the particular crop (Acquaah, 2002).

### 2.9.2 Constitution of organic manure

The use of organic manure especially cow dung, poultry droppings, household refuse for crop productivity is an age long agricultural practice amongst the subsistent farming communities in West African sub-region (Lombin *et al.*, 1991), though its use was confined mainly to small holdings around the home stead. Although considerable variation exists in the percentage nutrient composition of farm yard manure, depending on the source, handling and management, the main nutrients supplied are nitrogen, phosphorus and potassium and a host of micro-nutrients (Wikipedia, 2006). The NPK composition of farmyard manure as reported in a number of the francophone countries in West Africa notably: Senegal, Mali and Burkina Faso have been summarized by Mokwunye (1980) with variations of nutrient contents.

Cooke (1982) reported that an estimate of $10tha^{-1}$ farmyard manure would supply about 50kg N/ha, 30kg $P_20_5$/ha and 50kg $k_20$/ha.

Long term studies on organic manures largely improved soil physical conditions such as moisture retention capacity and aggregate soil stability, crop water use efficiency (Hati *et al.*, 2006), improve soil fertility, crop performance and yield (Kaur *et al.*, 2005; Sarkar *et al.*, 2003; Bokhtiar & Sakurai, 2005; Hossain & Ishmine, 2007; Tirol – Padre *et al.*, 2007). The zone of the soil nutrient concentration must be enhanced, should be moist and contain actively growing roots (Ihejirka *et al.*, 2009). This can be achieved by regulating the nutrient/water supply and/or accelerating root growth through modification of the soil physical environment (Maurya & Lal, 1981).

**2.9.3 Nutrient conservation**

Organic manure mulches have been observed to effectively conserve nutrient, moisture, etc within the soil effective rooting zone (Wikipedia, 2006). Swift & Anderson (1993) reported that organic manures supply nutrients which NPK could not supply.

**2.9.4 Farmyard manure**

Farm yard manure refers to the decomposed mixture of dung and urine of the farm animals along with litter and left over material from roughages or fodder fed to the cattle (Sankaranarayan, 2001). On an average, well decomposed farm yard manure contains 0.5 percent N, 0.2percent $P_205$ and 0.5 percent $K_2O$ (Pandey & Kumar, 1989). Asadu and Akamigbo (1990) also observed that organic matter contributes about 71% of cation exchange capacity in oxisols; 70% in ultisols and 58% in alfisols.

Wikipedia (2012) reported that there is reduced acidification, increased contents of exchangeable calcium thus enhancing root growth and uptake of Phosohorus when regular applications of organic matter is maintained. Moyin-Jesu & Adekayode (2010) reported that application of organic fertilizers increased significantly the soil and leaf N, P, K, Ca, Mg and soil organic matter under bitter kola seedlings in the nursery. The beneficial effects of organic manure on the nitrogen content of the soil has largely been demonstrated under prolonged use as shown by Tirol-Padre *et al.,* (2007). Moyin-Jesu (2009) reported that organic fertilizers were found to increase the soil N, P, K, Ca and Mg significantly ($P<0.05$).

The residual effect and especially nitrogen effect of farmyard manure usually lags behind that of the corresponding amount of soluble mineral fertilizer at first because in the first growing period only part (30-60%) of farm yard manure nitrogen becomes available, the rest is fixed at first or is reserved to build up the soil humus and nutrient supplies. This later starts to increase ($P= 0.05$) with regular application of farm yard manure (Prassad & Singh, 1980). After two or three applications both immediate effects and the delayed effects of earlier manure applications coincide and the manure starts to have its maximum impact on yields (Prassad & Singh, 1980). Tisdale & Nelson (1990) reported that Nitrogen is important in vegetative growth, protein synthesis and root formation of crops. Report from Uganda showed that farmyard manure can positively affect yields in the second and third subsequent cropping seasons. The residual effects of fertilizing with farmyard manure last well into the third or fourth year of cropping and subside more quickly in the tropics (Pietrowietz & Neumann, 1987).

Farmyard manure and household wastes are major sources of nutrients for food crop production in many parts of the tropics. Cow dung is also a potential source of plant nutrients but only in areas where animals are reared. The use of farmyard manure or compost as nutrient source of food crop production depends largely on the prevailing farming systems (Pieri, 1989). In some areas of East and Southern Africa where crop and livestock production are somewhat integrated, farmyard manure could become a major nutrient source for food crops and reduce need for fertilizer (Swift & Anderson, 1993). In the humid forest zones where livestock may be limited to a few sheep, goats or birds, in each compound farm, the use of crop residue becomes a source of nutrient input in the more permanent cropping systems which may replace slash and burn agriculture. In semi arid zone of West Africa composting is not a common practice because of the lack of water and crop residue (Poulain, 1980). However application of crop residue to acid Oxisols high in exchangeable aluminum has reduced the lime requirement (Adinigsih *et al*., 1998). Thus soyabeans grown in ultisols treated with crop residues have exhibited reduced aluminum toxicity (Ahmad and Tan, 1986) probably owing to the effect of organic acids in complexing toxic aluminum (Tan & Binger, 1986). Tsai *et al*. (1989) reported that yield of Sorghum increased by 20% when 20 metric tons of berseem clover were ploughed slightly under the soil as green manure and by 40% when 30metric tons of clover was applied.

### 2.9.5 Quality of poultry manure

Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average content of nutrients is 3.03 percent N, 2.63 percent $P_20 5$ and (14 percent $K_20$ (Marappan & Narayanan, 1993). The superiority of poultry manure over other organic manures has been confirmed (Follet *et al.*, 1981). Also Hsieh & Hsu (1993), Junadasa *et al.* (1997) have reported that poultry manure applications increased pH, organic matter content, available phosphorus, exchangeable cations and micronutrients and decreased soil salinity and extractable iron. Microbial activity and nutrient immobilization increased with soil organic matter (Tian *et al.,* 1994), and decomposition (Giller *et al.,* 1997). Babalola *et al.* (2000) reported that poultry manure when used as fertilizer usually stimulated microbial activities and thereby enhanced the release of inorganic nitrogen and phosphorus. Alagba *et al*. (2014) confirmed increased quantities of soil nutrients at post harvest period with application of 10-20 $tha^{-1}$ of poultry manure to sole and intercropped plots of kola and plantain.

Moyin-Jesu (1999) reported that organic manure significantly (P=0.05) increased the soil, leaf and chemical nitrogen, phosphorus, potassium, calcium, magnesium and growth parameters of tuber crops. Aisueni *et al.* (2009) reported that poultry manure enhances date palm seedling growth in the nursery and can be used as alternative soil fertility treatment to inorganic N and K. Moyin-Jesu and Adekayode (2010) also reported that application of poultry manure at the rate of 8 t $ha^{-1}$ to seedlings in the nursery gave highest values of plant height, leaf area, stem girth, leaf number, root length and fresh shoot weight (kg) of African cherry nut (*Chrysophyllum albidium*) compared to wood ash, pig manure and control treatments. This is further confirmed by the report of Moyin-Jesu (2009) that growth parameters of *Cola acuminata* seedlings including height, leaf area, leaf number, stem girth, shoot weight and tap root length were found to increase significantly ($P<0.05$) in the nursery by the use of different kinds of organic manure. Moyin-Jesu (2008) also reported that the effect of different kinds of organic manure in their sole and supplemented forms were significant in increasing growth parameters of bitter cola seedlings in the nursery. Obiefuna (1990) reported that plantains which received farm yard poultry manure established significantly (P =0.05) better in the field than those which received either refuse compost, cattle farm yard manure or the control which had the least survival. Ogazi (1996) reported that the high productivity of plantains under small holder compound production system is attributed to such house hold wastes including livestock waste, waste water, and wood ash thrown around the plantain mats. Under such conditions, plantain remains productive for many years because soil fertility is maintained at high level by household refuse and animal wastes while weeds are suppressed (Braide & Wilson, 1980).

In an experiment to determine the effect of poultry manure on two hybrid cultivars of plantain, Aba *et al.* (2011) reported that poultry manure at 10 t $ha^{-1}$ significantly ($P<0.05$) influenced general performance and productivity of plantain. This led to increased growth rate, earlier flowering, larger biomass, healthier canopy, earlier harvest and improved yield. This was due to nutrients released from poultry manure. Similar response has been observed in several other species including plantain (Obiefuna, 1990), pearl millet (Gupta *et al.*, 1983), passion fruit (Ani & Baiyeri, 2008), straw berry (Preusch *et al.*, 2004), and corn (Sims, 1987). The use of organic substrates in nurseries for mass propagation of Musa germplasm is necessary (Baiyeri & Aba, 2007) to enhance multiplication and subsequent plantlet growth (Aba *et al.*, 2011).

According to Aba *et al.* (2011), higher poultry manure rates (20 t ha $^{-1}$) led to yield decline and non significant plant growth response. This suggests that application of poultry manure at 10tha$^{-1}$ may be regarded as the optimal annual dose for plantains in the study area considering soil native fertility. This could be affirmed by higher bunch yield and harvest index (economic harvest) values obtained at 10t ha$^{-1}$ application. A strong positive correlation exists between harvest index (HI) and crop yield (Baiyeri *et al.*, 2005). HI defined as the proportion of the total accumulated biomass partitioned to the harvestable product is an indication of the crop's physiological efficiency in assimilates partitioning (Aba *et al.*, 2011). Furthermore, the decline in bunch yield and harvest index at 20t ha$^{-1}$ may have been attributed to the fact that due to higher quantities of Nitrogen which is responsible for vegetative growth, large biomass was produced to the detriment of bunch yield. Application of N fertilizer promotes vegetative growth sometimes to the detriment or disadvantage of the harvestable yield (Baiyeri, 2002).

Yield decline observed at higher doses of poultry manure could also be related to soil reaction and the consequent nutrient solubility or fixation and inbalances which can occur when large amounts of compost and poultry manure are used (Ijoyah. 2007). Soil pH increases progressively with the application and subsequent decomposition of poultry manure (Amanullah, 2007). Phillip *et al.* (2009) reported that application of poultry manure significantly ($P<0.05$) raised returns from both plantain and Telfairia production with optimum rate of application being 80$tha^{-1}$ for sole plantain as well as plantain – Telfairia intercrop and 40t $ha^{-1}$for sole Telfairia production.

Poultry manure is very rich animal manure (Gupta *et al.*, 1997). Heavy poultry manure (10 to 50 $tha^{-1}$) gave optimum response of marketable yield of *Corchorus olitorius* cabbage (Holchmut *et al.,* 1993), peppers egg plant, tomatoes and okra (Maynard, 1991; Hussein, 1997; Aratolu, 1998).

### 2.9.6 Organic versus inorganic manure

In comparing yields of organic and conventional or inter mediate farm produce, a U.S. survey published in 2001 analyzed 150 growing seasons of data on various crops and concluded that yields from organically grown crops were 95-100% of conventional yields because organic farms do not use toxic pesticides and herbicides, there is more biodiversity in the soil. Besides higher soil quality, more life in the soil allows for higher water retention. This helps to increase yield for organic farms in drought years where there is less rain, organic farms have been found to have yield, 20-40% higher than conventional farms (Wikipedia, 2006). A similar study in Taiwan by Hsieh (1992) revealed that the application of composted chicken manure gave as good a grain yield of rice (7.43 t $ha^{-1}$) as that from conventional farming which depended solely on chemical fertilizer. In another experiment conducted by Hsieh *et al.* (1992) to determine the effect of organic and inorganic fertilizers on yield and quality of sweet corn and vegetable soyabean, the fresh ear yield of sweet corn harvested from organic plots (hog and poultry manure) was equivalent to that of corn given chemical fertilizer ($N\text{-}P_2O5\text{-}K_20$, 200-60-60kg $ha^{-1}$) except for the plot with cattle manure which gave lower yield. However, the nitrogen and magnesium content of the corn grain were significantly higher in corn from plot with chemical fertilizer while phosphorus and potassium was slightly higher in the organic plot than in the chemical plot.

The effect of organic manures on food quality and nutrient content have also be reported. Wikipedia (2006) reported that organically grown potatoes, oranges and leafy vegetables have more vitamin C than conventionally grown foods. Phenolic compounds are found in significantly higher concentration in organic foods and these may provide anti-oxidant protection against heart disease and cancer. Increased soil quality, greater attention to quality and selection of crop varieties for nutrition and taste instead of size, appearance and shipping characteristics are claimed to be reason for high nutrient density of organic foods. Still isolated bits of research are suggesting that conventional agricultural practices are degrading food quality. A study in the Journal of the American College of Nutrition (2004), compared vegetables analyzed in 1950-1999 and found noticeable decreases in six of thirteen nutrients examined (the six were protein, calcium, phosphorus, iron, riboflavin and ascorbic acid). Percentage reductions ranged from 6% for protein to 35% for riboflavin although when evaluated on per food and per nutrient level usually no distinguishable change was found.

**2.9.7 Effect on pests and diseases**

Organic manure has also been shown to affect significantly the disease and pest resistance ability of crops. Ihejirika *et al.* (2009) reported that soil amendment using poultry manure significantly (P=0.05) influenced field disease severity (Anthracnose, Kola mosaic, kola leaf curl and kola blight) with least severity recorded at poultry manure rate of 20 t $ha^{-1}$ followed by 10 t $ha^{-1}$ while 0t$ha^{-1}$ (control) had the highest disease severity. This may be attributed to the fact that poultry manure possesses the capability of ecological production management system that promotes and enhances biodiversity, biological cycles, soil biological activity that encourages nutrient availability for healthy growth of kola seedlings. This restores, maintains and enhances ecological harmony in line with Cummis (2006). It also decreases soil salinity and extractible ions immobilization (Tian *et al.,* 1994; Giller *et al.,* 1997). All these provide an unconduscive environment for disease incidence, symptom manifestation and spread. Low severity of field diseases encourages high yield of many crops as they respond to organic manure especially poultry manure (Ihejirika *et al.*, 2009). Apart from the fact that proper manure enhances crop yield on most soils (Maynard, 1991), it also sustains plants capacity to resist disease attack and the superiority of poultry manures have been confirmed in many experiments (Follet *et al.,* 1981). Generally, pests and pathogens responsible for the field disease are attracted to inferior or weak plants, the result of crop nutrition (Anon, 1998). This means that they are naturally repelled by vigorous, well-nourished plants (Ihejirika *et al.*, 2009). Diseases and pest incidence and severity are significantly reduced by the use of poultry manure and intercropping. This is confirmed by Ihejirika *et al.* (2009) who reported that intercropping and poultry manure interaction had significant effects on anthracnose, blight, mosaic and leaf curl diseases on kola seedlings. The significant effect of interaction between soil amendment using poultry manure and kola intercropped with maize, melon and cassava in all field diseases may have been attributed to the ideal interactive role of nutrient availability of poultry manure and complimentary use of growth resources such as water, nutrient and sunlight coupled with reduced soil erosion, as a result of dense and diversified root system and reduced leaching by intercropping. All these provide barriers against pathogen penetration, attack and symptom manifestation (Ihejirika *et al.,* 2009)

### 2.9.8 Challenges of organic manure

Aquaah (2002) reported that organic production of crops is not without its problems or criticism. It is generally a more expensive cultural practice. Furthermore people are willing to pay more for organically produced food crops because of the fear of pesticides and herbicides. However, the absence of chemicals in the production system many encourage the presence of natural toxins which could also be harmful and both pests and diseases build up is also increased under this system (Acqaah 2002).

# CHAPTER THREE

# METHODOLOGY

## 3.1 Experimental site

The experiment was conducted from November 2010 to January 2013 at the Teaching and Research farm of the Federal University of Technology, Owerri located between latitudes $5^o$ 27,50.23´´ and $5^o$ 29´ 44. 18´´ North and longitude $7^o$20´ 19.35´´ and $7^o$02´ 56.12´´East at an elevation of 55.6m above sea level.

## 3.2 Climate and vegetation of the site

The climate of Owerri is a humid tropical type characterized by wet and dry season. The two seasons are influenced by the humid maritime air mass. The wet or rainy season begins in mid –march and ends in November with a little dry spell (called August Break) occurring in August. The dry season starts in mid November and ends in mid March. The mean annual rainfall is 2500mm and is bimodal with peaks in July and September (Nwosu and Adeniji, 1980).

The minimum and maximum temperatures are $20^o$ C and $32^o$ C, respectively. The area is characterized by deep porous soils derived from sand deposits in the coastal plains which are highly weathered, low in mineral reserve and natural fertility (Ofomata 1995; Onweremadu, 2007; Ononiwu, 1990). Thus farmers in the area practice bush fallowing as a means of improving soil fertility.

## 3.3 Pre and post experimental soil physico –chemical characterization

Soil samples were collected randomly from experimental sites using soil auger at a depth of 0-60cm, 60-80cm and 80-100cm for physical and chemical analyses. The collected soil samples were air- dried in the laboratory, ground and sieved (Sieve pan). The particle size fraction was determined by hydro-meter method of Bouyocous (1951) using sodium hexameta phosphate as a dispersant.

Soil pH was determined in distilled water and KCl on a ratio of 1:2.5 soil/solution using a pH meter (Corning pH meter model 17).

The Bray No 2 method was used to determine available phosphorous. Exchangeable potassium and sodium were determined by the flame photometry while calcium and magnesium contents were determined by the Versenate 0.1m Ethylene diameter tetra acetate (0.1m EDTA) titration method. Effective CEC was determined by summation of exchangeable bases plus exchangeable acidity, and acidity was determined by 1 N KCL procedure as outlined by Mclean (1965). The total Nitrogen content was determined by the modified micro Kjeidahls digestion method (Jackson, 1969). The percentage organic carbon content of the soil was determined using dichromate wet oxidation method of Walkey and Black as outlined by Jackson (1969). The base saturation was determined by expressing the the sum of exchangeable bases as a percentage of the effective cation exchange capacity.The post experimental soil samples were collected randomly from each treatment plot, bulked treatment by treatment and analyzed as described above.

### 3.4 Determination of nutrient content of poultry manure

Samples of cured poultry manure were collected randomly from the bulk, air dried in the laboratory under room temperature for 3 days. The pH was determined in distilled water at a ratio of 1:2.5 poultry manure/solution using a pH meter (Corning pH meter model 17). The total Nitrogen was determined by the modified micro-Kjeldahl digestion-distillation procedure (Jackson, 1969). The percentage organic carbon content of the poultry manure was determined using dichromate wet oxidation method of Walkey and Black as outlined by Jackson (1969). The Bray No 2 method was used to determine available phosphorous. Exchangeable Potassium and Sodium were determined by the flame photometry while Calcium and Magnesium contents were determined by the Versenate 0.1m Ethylene diameter tetra acetate (0.1m EDTA) titration method. Sulfur, copper, manganese, iron and zinc contents of poultry manure were determined by the Per-chloric acid digestion wet oxidation method as outlined by IITA (1981).

### 3.5 Determination of nutrient content of mulch materials

Samples of saw dust, wood shavings, trash, and palm fronds were collected randomly from bulk, air dried in the laboratory under room temperature for 7 days and analyzed for organic matter, organic carbon, total Nitrogen, available Phosphorus,exchangeable Potassium, Calcium, Sodium and Magnesium, Iron, Manganese, Sulfur, cupper and zinc, contents as described in 3.4 above.

### 3.6 Experimental design

Allocation of various treatments was done using the Gomez and Gomez (1984) Table of Random Numbers. The treatments were three trench depths (60x60x60cm, 60x60x80cm, 60x60x100cm) and six mulch materials (sawdust, wood shavings, palm fronds, trash, black polythene sheet and no mulch, which is the control). The 18 treatment combinations were laid out in 3x6 factorial and fitted into a Randomized Complete Block Design (RCBD) and replicated three times.

### 3.7 Land preparation and planting

A three year fallow farm was slashed, packed and stumped. Each experimental plot was marked out. Each plot measured 10x3m and there were 18 plots in each replication. The total land area was 1530m$^2$ with 1m alley at the boundaries of the experimental plot.Trench depths of 60x60x60cm (60cm depth), 60x60x80cm (80cm depth) and 60x60x100cm (100cm depth) for plantain were dug in November, 2010, during which time the top soil dug out from each hole was kept on one side different from the sub soil as prescribed by CTA (1987). Uniform plantain sword suckers (30cm height) were planted at a spacing of 3.0x2.0m in the first week of December 2010. Each sword sucker was put in each hole and covered with top soil from the hole.There were 5 stands of plantain per plot, 90 stands of plantains per replication and a total of  270 stands of plantain. All 5 plants in each plot were sample plants.

### 3.8 Planting materials

The plantain sword suckers (Musa AAB Ogoni Red) were dug from the University plantain orchard. The sword suckers were harvested, pruned to a height of 30cm and planted within one week.

### 3.9 Poultry manure application

Cured and dried poultry manure was procured from theUniversity Livestock Farm. The poultry manure was applied at the rate of 10 t $ha^{-1}$ in 2 split doses. The first ose was applied in situ at planting while the second dose was applied in April (four months later). Each plant received a total of 6kg (3kg at each application). In each application poultry manure was incorporated in each depth and spread in a circumfernce around the base of the pseudostem after covering the pseudostem with top soil dug out from the planting hole.The manure was spread to cover the entire base of the planting hole.

### 3.10 Mulching

Five different mulch materials namely; sawdust, wood shavings, palm fronds, black polythene, and trash were used. The Saw dust and wood shavings were obtained from Owerri timber market, transported to the site and dried under the sun for two weeks. The palm fronds were procured from a palm plantation at Umuapu, Ohaji, transported to the farm, chopped and dried under the sun for two weeks before application. The trash which constituted a composite of vegetation cleared from the experimental site was also sun dried for ttwo weeks before application. The control plot was manured but unmulched. After planting the suckers, 2kg of each mulch except the black polythene was weighed out on a scale and applied to specific trench depths of 60, 80 and 100cm respectively. The mulch was spread around the base of the plantain pseudostem above the poultry manure layer. The black polythene was perforated and spread at the base of the plantain above the poultry manure layer.

### 3.11 Soil sampling

Core samples from each plot were collected using soil auger at 1,2 and 3 months after planting to determine the percentage soil moisture content and soil macro biological life.The soil macrobiological life identified were big black ants (*Doryllus nigiricans),* crickets (*Gryllus bimaculata), e*arthworms (*Eudrillus eygeniea),* millipedes (*Julius spp),* termites (*Macrotemes bellicocus)* and snails (*Achatina fulica*) in each plot. The samples were collected at a distance of 15cm from the base of the plantain at a depth of 0-15cm and 15-30cm from the base of the planting holes. Soil macro biological life was identified in core samples of 0-15cm depth from the base of the planting holes while percentage soil moisture content was determined from core samples of 0-15cm and 15-30cm from the base of the planting holes.

### 3.12 Determination of moisture content in core samples

The moisture content in each core sample was determined by the gravimetric method. This was done by taking the fresh weight of 10g of representative soil samples from each core sample. The samples were dried in the oven for 48 hours and the dry weight was determined by using the electronic scale. The percentage moisture content was determined using the formula as follows:

$$\%\ \text{moisture content} = \frac{\text{fresh weight} - \text{dry weight}}{\text{fresh weight}} \times \frac{100}{1}$$

### 3.13 Determination of soil biological life (macro)

The soil biological life (earth worms, termites millipedes crickets, big black ants etc) contained in each core sample was determined by taking a physical count of all organisms found in each core sample and identified by number and type of each organism supported by each mulch material at each trench depth.This was done according to specifications by Moriera *et al.* (2008).

### 3.14 Soil temperature determination

The soil temperature at each depth of planting and mulch source was determined with the use of soil thermometers. The soil thermometers were inserted at the depth in each planting hole from January to April. Temperatures were recorded at 13 hours, daily and averaged for months.

### 3.15 Replanting

Replanting was done three months after planting. This was to ensure that all sword suckers had ample time to sprout, failure of which it was assumed that they will not sprout and replanting was done at the expiration of three months. The dead plantain sword suckers were replaced with new ones.

### 3.16 Weeding and weed sampling

The plots were weeded manually by slashing every three months. At each weeding a quadrate was placed at random in each plot to collect weed samples for identification, drying and weighting. The weeds were oven dried at $60^0$C for 36hours and then weighed with the electronic scale. Predominant weed samples were identified using the weed hand book (Akobundu & Agyakwa, 1987).

### 3.17 Pests and disease

#### 3.17.1 Pest

The pest of plantain was assessed during establishment and growth. The variegated grasshopper (*Zonocerus variegatus*) was identified and the level of damage on the plantain leaves was scored using the IITA (1992) standard scoring system (scale 1-5) and recorded for all affected plants as follows:

| Scale | | Interpretation |
|---|---|---|
| 1 | - | No damage observed |
| 2 | - | Mild insect damage on the leaves |
| 3 | - | Strong insect damage on the leaves |
| 4 | - | Very strong insect damage on the leaves |
| 5 | - | Severe damage on the leaves |

### 3.17.2 Disease

Black Sigatoka leaf spot disease of plantain was recorded using visual observation and scored by counting the number of leaves affected by the disease and expressed it as a percentage of the total number of leaves on the sample plant according to the format by Foster *et al.* (1981) below:

| Severity% | Scale | Interpretation |
|---|---|---|
| 0 | 0 | No infection |
| 1-20 | 1 | Slight infection |
| 21-40 | 2 | Moderate infection |
| 41-60 | 3 | Severe infection |
| 61-80 | 4 | Very severe infection |
| 81-100 | 5 | Complete infection |

## 3.18 Data collection

### 3.18.1 Percentage sucker sprout

The percentage survival count was determined by taking a physical count of all surviving plants per plot, and then expressed as a percentage. Three plants were sampled per plot. The percentage sucker sprout per plotwas determined by taking a physical count of all sprouted sample plants per plot as a percentage of the total number of sample plants per plot based on the formula below :

$$\% \text{ Sucker Sprout / plot} = \frac{\text{number of sprouted suckers / plot}}{\text{total number of suckers/plot}} \times \frac{100}{1}$$

### 3.18.2 Pseudostem height (cm)

The plantain pseudostem height was measured with a meter rule placed from the ground to the V point of the last opening leaves at six and nine months after planting and at harvest of plant crop and harvest of first ratoon crop. The mean height per plot was obtained by summation of the height of all the sample plants and dividing by the number of sample plants per plot.

### 3.18.3 Pseudostem girth (cm)

The pseudostem girth was measured 10cm from the ground with a measuring tape placed around the girth and read off at six and nine months after planting and at harvest of plant crop and harvest of first ratoon crop. The mean girth per plot was obtained by summation of the girth of all the sample plants and dividing by the number of sample plants per plot.

### 3.18.4 Number of leaves

The number of leaves per plant for each plot was obtained by taking a physical count of all the leaves on each plant at six and nine months after planting and at harvest of plant crop and harvest of first ratoon crop. The mean number of leaves per plot was obtained by summation of the number of leaves on all the sample plants and dividing by the number of sample plants.

### 3.18.5 Leaf area and leaf area index

The leaf area (LA) of plantain was obtained using the method outlined by Obiefuna & Ndubuizu (1979) involving the measurement of the mid rib length (L) and the maximum width (W) of the third leaf from the top. The equation is given below:

Leaf area = 0.8 (LxW) of sample plant (Ndubuizu & Obiefuna, 1979)

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Total land area occupied by plant}}$$

$$= \frac{\text{Leaf area}}{1.5\text{m}^2}$$

Mean leaf Area per plot was obtained by summation of the leaf areas per plot of sample plants and dividing by the number of sample plants. This was done at six and nine months after planting and at harvest of plant crop and harvest of first ratoon crop.

### 3.18.6 Number of suckers

The number of suckers formed per plant was determined by taking a physical count of number of suckers formed from each parent plant six and nine months after planting and at harvest of plant crop and at harvest of first ratoon crop. The mean number of suckers per plot was determined by summation of suckers from all sample plants and diving by the number of sample plants per plot.

### 3.18.7 Days to 50% flowering

**T**he number of days to 50% flowering in each plot was determined by counting the number of days taken for 50% of the sample plants to flower (shoot) in each plot and dividing it by the number of 50% of the sample plants in the plot .

### 3.18.8 Harvest of plantain

The plantains were harvested 120 days after shooting as at when plantains matured in each plot and weighed with 50 kg Saltar scale. The bunch weights were converted to tons per hectare while the number of hands and fingers were determined by taking a physical count of the hands in each bunch and fruits (fingers) in each hand.

#### 3.18.9 Rate of high mat development

Rate of high mat growth was determined by reading the mat height on the graduated iron meter rule inserted to each depth. Readings were taken after harvest of first ratoon crop. The distance (height) covered by the mat from the planting depth (cm) to the present height on the graduated rule was divided by the time taken (months) to determine the rate of high mat development.

#### 3.18.10 Height of plantain mat

This was determined by reading the graduated meter rule inserted to each depth for the mat height at harvest of first ratoon crop of each treatment.

### 3.19 Statistical analysis

The analysis of variance (ANOVA) was used to test for significance among the treatment means using Genstat discovery edition (Genstat Realse 4.24DE, 2005). Treatment means were separated using least significant difference (LSD) at 5% level of probability according to the statistical procedure of Obi (2002) while correlation coefficient analysis was performed using the SPSS software package version 17.

### 3.20 Input output cost analysis

**T**he input output cost analysis was computed to determine the profitability of the different treatments.The input consisted of the cost of land clearing (man days/ha), digging holes, plantain sword suckers, procurement, loading, off loading, transportation of all mulch materials, and poultry manure, planting labour, weeding labour (mandays/ha), desuckering and harvesting labour.The output consisted of the total revenue obtained from sale of plantain suckers and plantain bunch (t $ha^{-1}$) for plant and first ratoon crops. The profit was obtained by subtracting the total cost of input from the total revenue based on the formula below:

Total profit = total revenue – total input cost

The benefit-cost ratio was obtained by dividing the total revenue by the total cost based on the formula below:

$$\text{Benefit-cost ratio} = \frac{\text{Total revenue}}{\text{Total cost}}$$

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 RESULTS

### 4.1.1 Soil physico-chemical characterization at pre-experimental period

The pre-planting soil physico-chemical analysis is shown in Table 1. In the different trench depths (60, 80 and 100cm) respectively soil pH in $H_20$ (5.10, 4.82, 4.40), organic carbon (0.42, 0.21 and 0.05), organic matter (0.72, 0.37, 0.10), total nitrogen (0.30, 0.01 and 0.10) contents were low. This indicates a slightly acidic and infertile soil. Also the base saturation suggests the dominance of 1:1 clays, indicating hjgh level of acidity. Generally, the soil showed poor fertility and belongs to the sandy clay loam class.

### 4.1.2 Chemical properties of poultry manure

The chemical properties of the poultry manure for the experiment is shown in Table 2. The chemical analysis indicates an alkaline pH (8.20), high contents of organic matter (50.53), nitrogen (2.74%), potassium (0.95cmol $kg^{-1}$), phosphorus (0.34cmol $kg^{-1}$), calcium (3.62cmol $kg^{-1}$), magnesium (1.82 cmol $kg^{-1}$) while the carbon: nitrogen ratio stood at 1:4.

### 4.1.3 Chemical content of mulch materials

Table 3 shows the chemical content of the different mulch materials used for the experiment. The highest nitrogen content was recorded in palm frond (1.03%) while potassium and available phosphorus contents were highest in wood shavings (5.17cmol $kg^{-1}$ and 10.08mg $kg^{-1}$), palm frond mulch had the highest content of magnesium (2.68cmol $kg^{-1}$), lignin (16.12%) and sulfur (2.13cmol $kg^{-1}$), wood shavings had the highest content of ash (5.02%), zinc (5.80 $cmolkg^{-1}$), copper (1.34$cmolkg^{-1}$) and carbon (51.23%), while trash had the highest content of iron (2.61 $cmolkg^{-1}$), manganese (2.19$cmolkg^{-1}$) and water (3.62%). The highest cellulose content was recorded in palm wood shavings and saw dust (34.90%, 34.90%) respectively, caicium was highest in saw dust (1.83$cmolkg^{-1}$)

**Table 1: Pre-planting soil physico-chemical characterization of the experimental site in 2010.**

| **Trench depth (cm)** | | | |
|---|---|---|---|
| **Characteristics** | **60cm** | **80cm** | **100cm** |
| pH in H20 | 5.10 | 4.82 | 4.70 |
| pH in KCl | 4.98 | 4.71 | 4.52 |
| Exchangeable Hydrogen (cmol $kg^{-1}$) | 0.30 | 0.60 | 0.50 |
| Total Nitrogen (%) | 0.30 | 0.01 | 0.10 |
| Available Phosphorus (mg $kg^{-1}$) | 0.62 | 0.21 | 1.15 |
| Aluminium (cmol$kg^{-1}$) | 0.40 | 0.80 | 0.60 |
| Exchangeable cations (cmol $kg^{-1}$) | | | |
| Calcium (cmol $kg^{-1}$) | 1.80 | 1.20 | 0.80 |
| Magnesium (cmol $kg^{-1}$) | 1.00 | 0.80 | 0.80 |
| Potassium (cmol $kg^{-1}$) | 0.12 | 0.21 | 0.17 |
| Sodium (cmol $kg^{-1}$) | 0.15 | 0.16 | 0.13 |
| Total acidity (cmol $kg^{-1}$) | 0.70 | 1.40 | 1.10 |
| ECEC (cmol $kg^{-1}$) | 3.77 | 3.77 | 3.00 |
| Soil organic matter (%) | 0.72 | 0.37 | 0.10 |
| Soil organic carbon (%) | 0.42 | 0.21 | 0.05 |
| Base saturation | 81.40 | 62.80 | 61.33 |
| Percentage silt (%) | 2.00 | 2.00 | 2.00 |
| Percentage clay (%) | 21.20 | 21.20 | 21.20 |
| Percentage sand (%) | 76.80 | 76.80 | 76.80 |
| Textural class | SCL | SCL | SCL |

SCL= Silt clay loam

**Table 2: Chemical properties of poultry manure for experiment in 2010**

| Characteristics | Value |
|---|---|
| pH ($H_20$) | 8.20 |
| Nitrogen (%) | 2.74 |
| Calcium (cmol $kg^{-1}$) | 3.62 |
| Potassium (cmol $kg^{-1}$) | 0.95 |
| Phosphorus (mg $kg^{-1}$) | 0.39 |
| Organic carbon (%) | 27.15 |
| Magnesium (cmol $kg^{-1}$) | 1.82 |
| Lignin (%) | 0.51 |
| Sulfur (cmol $kg^{-1}$) | 1.14 |
| Ash (%) | 0.82 |
| Cupper (cmol $kg^{-1}$) | 0.04 |
| Iron (cmol $kg^{-1}$ | 0.39 |
| Zinc (cmol $kg^{-1}$) | 0.19 |
| Manganese (cmol $kg^{-1}$) | 0.31 |
| Water (%) | 0.54 |
| Cellulose (%) | 0.72 |
| Organic matter (%) | 50.53 |
| Carbon: Nitrogen Ratio (C:N) | 10:1 |

**Table 3: Chemical properties of mulch materials for experiment in 2010**

| **Sample** | **N** (%) | **Ca** ($cmolkg^{-1}$) | **K** ($cmolkg^{-1}$) | **P** ($mgkg^{-1}$) | **Mg** ($cmolkg^{-1}$) | **Lignin** (%) | **S** ($colmk^{1}$) | **Ash** (%) | **Cu** ($colm/kg^{-1}$) | **Fe** ($cmol kg^{-1}$) | **Zn** ($cmolkg^{-1}$) | **Mn** ($cmolkg^{-1}$) | **C** (%) | **$H_2O$** ( %) | **Cellulose** (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wood shavings | 0.14 | 1.82 | 5.17 | 10.08 | 1.61 | 11.19 | 0.41 | 5.02 | 1.34 | 2.25 | 5.80 | 1.71 | 51.23 | 1.92 | 34.90 |
| Palm frond | 1.13 | 0.93 | 3.06 | 3.95 | 2.68 | 16.12 | 2.13 | 2.56 | 0.04 | 0.06 | 0.03 | 0.08 | 31.40 | 2.79 | 21.12. |
| Trash | 0.17 | 1.31 | 3.26 | 0.24 | 1.65 | 6.36 | 1.26 | 3.76 | 1.19 | 2.61 | 2.53 | 2.19 | 11.31 | 3.62 | 21.10 |
| Saw dust | 0.14 | 1.83 | 5.16 | 10.06 | 1.59 | 11.12 | 0.42 | 4.90 | 1.33 | 2.24 | 5.71 | 1.72 | 51.20 | 1.89 | 34.90 |
| Black Polythene | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

NA: Not Applicable

### 4.1.4 Rainfall data for December, 2010 – Decembr, 2013

Table 4 highlights rainfall data (mm) for Owerri zone from December 2010 to December, 2013. The highest rainfall in 2011 was recorded in August (465.8mm) while June 2012 witnessed the highest rainfall (518.5mm), May 2013 produced the highest rainfall (330mm) while December 2010, Jan. 2011, January 2012 and December 2012 witnessed no rainfall.

### 4.1.5 Soil macro biological life

**One month after planting (January, 2011).**

The population of soil macro biological life at one month after planting (Table 5) indicated highly significant ($P<0.05$) effect of trench depth and mulch materials ($P<0.05$) on the population of big black ants. The 100cm trenches mulched with trash recorded the highest number (4.65) of big black ants (*Doryllus nigiricans*) while the control plots (manured but unmulched) of 60cm depth recorded the least (0.33). There was no significant interaction effect between trench depth and mulch materials. Populations of crickets (*Gryllus bimaculata*) and earth worms (*Eudrilus eygeniea)* were not significantly influenced by all mulch materials, trench depth and their interaction.

Table 6 shows the effect of trench depth and mulch materials on the populations of millipedes (*Julius spp*), termites (*Macrotemes bellicocus*) and snails (A*chatina fulica*) at one month after planting (January 2011). There was a significant ($P<0.05$) effect of mulch materials on the populations of millipedes and termites ($P<0.05$). Trench depths of 60cm and 80cm mulched with palm frond had the highest (1.0, 1.0) populations of millipedes. There were no millipedes in trenches mulched with saw dust, wood shavings, black polythene and the control plots (manured but unmulch) irrespective of the depth. Highest population of termites (22.67) was recorded in 60cm trenches mulched with trash, followed by 60cm trenches mulched with palm frond (20.00). No termites were recorded in all trenches mulched

**Table 4: Rainfall data (mm) for Owerri zone from December 2010 to December 2013**

| Months | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| January | | 0.0 | 0.0 | 59.3 |
| February | | 131.9 | 90.9 | 56.5 |
| March | | 75.0 | 55.3 | 83.2 |
| April | | 99.2 | 187.4 | 198.7 |
| May | | 413.3 | 306.1 | 330.7 |
| June | | 196.8 | 518.5 | 185.9 |
| July | | 289.5 | 516.0 | 263.1 |
| August | | 465.8 | 367.7 | 243.6 |
| September | | 283.8 | 493.9 | 254.2 |
| October | | 257.9 | 211.8 | 159.9 |
| November | | 69.8 | 86.2 | 56.5 |
| December | 0.0 | 130.0 | 0.0 | 84.1 |

Source: Imo ADP Agro Meteorological Station Owerri

**Table 5: Effect of trench depth (cm) and mulch materials on the population of big black ant (*Doryllus nigiricans*),crickets (*Gryllus bimaculata*) and earth worms (*Eudrilus eygeniea*) at 1 month after planting in late season plantain (Jan, 2011).**

| **Soil biological life** | **Big black ants** | | | | **Crickets** | | | | **Earth worms** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 2.00 | 3.67 | 4.65 | 3.44 | 0.68 | 0.68 | 0.33 | 0.56 | 0.34 | 0.00 | 0.00 | 0.11 |
| Wood shaving | 0.68 | 0.67 | 1.00 | 0.78 | 0.33 | 0.32 | 0.33 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 1.67 | 1.68 | 3.00 | 2.11 | 0.32 | 0.31 | 0.33 | 0.33 | 0.33 | 0.00 | 0.00 | 0.11 |
| Saw dust | 0.68 | 0.66 | 1.00 | 0.78 | 0.69 | 0.35 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 1.00 | 1.34 | 1.35 | 1.22 | 0.65 | 0.00 | 0.00 | 0.22 | 0.32 | 0.00 | 0.00 | 0.11 |
| No mulch | 0.33 | 0.67 | 1.33 | 0.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mean | 1.06 | 1.44 | 2.06 | 1.52 | 0.44 | 0.28 | 0.17 | 0.29 | 0.17 | 0.00 | 0.00 | 0.06 |
| $LSD_{(0.05)}$ Mulch | | 0.75 | | | | ns | | | | ns | | |
| $LSD_{(0.05)}$ Trench depth | | 0.53 | | | | ns | | | | ns | | |
| $LSD_{(0.05)}$ Mulch x trench depth | | ns | | | | ns | | | | ns | | |

**Ns= Not significant**

**60cm=60x60x60cm dimension, 80cm=60x60x80cm dimension, 100cm=60x60x100cm dimension**

**Table 6: Effect of trench depth (cm) and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemes bellicosus*) and snails (*Achatina fulica*) in late season plantain at 1 month after planting (Jan, 2011).**

| **Soil biological life** | **Millipedes** | | | | **Termites** | | | | **Snails** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** |
| Trash | 0.34 | 0.34 | 0.67 | 0.44 | 22.67 | 19.68 | 19.00 | 20.43 | 0.00 | 0.33 | 0.00 |
| Wood shaving | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 1.00 | 1.00 | 0.33 | 0.78 | 20.00 | 17.66 | 17.32 | 18.33 | 0.00 | 0.00 | 0.00 |
| Saw dust | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| No Mulch | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.67 | 1.00 | 0.89 | 0.00 | 0.00 | 0.00 |
| Mean | 0.22 | 0.22 | 0.17 | 0.20 | 7.28 | 6.33 | 6.22 | 6.61 | 0.00 | 0.06 | 0.00 |
| LSD $_{(0.05)}$ Mulch | | 0.26 | | | 1.13 | | | | ns | | |
| LSD $_{(0.05)}$ Trench depth | | ns | | | 1.80 | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | ns | | | Ns | | | | ns | | |

ns. = Not significant

**60cm=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm=60x60x100cm dimension**

With saw dust, wood shavings and black polythene. Trench depth also had a significant (P<0.05) influence on termite population. The effect of interaction between trench depth and mulch materials was not significant on millipede and termite populations. Snail population was not significantly influenced by trench depth, mulch materials or their interaction at one month after planting (MAP).

**Two months after planting (February 2011)**

The effect of mulch materials and trench depth on the populations of big black ants (*Doryllus nigiricans*), crickets (*Gryllus bimaculata*) and earth worms (*Eudrilus eygeniea*) at two months after planting (MAP) is shown on Table 7. Results indicate that mulch materials and trench depth significantly (P<0.05) favoured large population of big black ants respectively. While trenches of 100cm depth mulched with trash recorded the highest number (4.33) of big black ants, the control (manured but unmulched) plots of 60cm depth recorded the least number (0.32) of big black ants.Trench depth, mulch materials and their interaction stimulated insignificant population of crickets and earth worms.

At two months after planting (Table 8) millipede and termite populations increased significantly (P<0.05) as influenced by mulch materials while termite population was significantly (P<0.05) influenced by mulch materials and trench depth. Trenches measuring 80cm and 100cm and mulched with palm frond recorded highest (0.67, 0.67) population of millipedes respectively. No millipedes were recorded in all trenches mulched with wood shavings, saw dust, black polythene and control plots. The highest number of termites was recorded in 60cm trenches mulched with trash (20.00), closely followed by 80cm trenches mulched with same (18.67). The shallow (60cm depth) and medium (80cm depth) trenches mulched with palm fronds also recorded high population (17.57 and 16.66) of termites respectively. All trenches mulched with saw dust, wood shavings and black polythene had no termites.  There were no snails in all trench depths at two MAP.

**Table 7: Effect of trench depth (cm) and mulch materials on the population of big black ant (*Doryllus nigiricans*),crickets (*Gryllus bimaculata*) and earth worms (*Eudrilus eygeniea*) in late season plantain at 2 Months after planting (February, 2011).**

| **Soil biological life** | **Big black ants** | | | | **Crickets** | | | | **Earth worms** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 2.00 | 3.00 | 4.33 | 3.11 | 0.68 | 0.32 | 0.35 | 0.45 | 0.36 | 0.34 | 0.00 | 0.23 |
| Wood shaving | 1.00 | 1.00 | 1.00 | 1.00 | 0.31 | 0.34 | 0.33 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 1.68 | 1.67 | 3.00 | 2.11 | 0.67 | 0.36 | 0.33 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 |
| Saw dust | 1.00 | 1.00 | 1.67 | 1.22 | 0.33 | 0.30 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 1.00 | 1.35 | 1.33 | 1.23 | 0.66 | 0.33 | 0.00 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| No mulch | 0.32 | 0.65 | 1.34 | 0.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.10 |
| Mean | 1.17 | 1.44 | 2.11 | 1.57 | 0.44 | 0.28 | 0.17 | 0.30 | 0.11 | 0.06 | 0.00 | 0.05 |
| $LSD_{(0.05)}$ Mulch | | | | 0.97 | | | ns | | | ns | | |
| $LSD_{(0.05)}$ Trench depth | | | | 0.68 | | | ns | | | ns | | |
| $LSD_{(0.05)}$ Mulch x trench depth | | | | ns | | | ns | | | ns | | |

ns. = Not significant

**60cm=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm=60x60x100cm dimension**

**Table 8: Effect of trench depth (cm) and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemes bellicocus*) and snails (*Achatina fulica*) in late season plantain at 2 months after planting (February, 2011).**

| **Soil biological life** | **Millipedes** | | | | **Termites** | | | | **Snails** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench** | | | | **depth** | | | | **(cm)** | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 0.00 | 0.33 | 0.00 | 0.11 | 20.00 | 18.67 | 15.33 | 18.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wood shaving | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 0.35 | 0.67 | 0.67 | 0.57 | 17.57 | 16.66 | 13.68 | 15.97 | 0.00 | 0.00 | 0.00 | 0.00 |
| Saw dust | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| No mulch | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.67 | 0.67 | 0.56 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mean | 0.11 | 0.17 | 0.06 | 0.11 | 6.33 | 6.00 | 4.94 | 5.76 | 0.00 | 0.06 | 0.00 | 0.00 |
| LSD $_{(0.05)}$ Mulch | | 0.26 | | | | 1.08 | | | | | Ns | |
| LSD$_{(0.05)}$ Trench depth | | ns | | | | 0.76 | | | | | Ns | |
| LSD$_{(0.05)}$Mulch x trench depth | | ns | | | | ns | | | | | ns | |

ns. = Not significant

**60cm=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm=60x60x100cm dimension**

**Three months after planting (March 2011).**

Table 9 showed no significant influence of trench depth (cm), mulch materials and their interaction on the population of crickets and earthworms at three monhs after planting. However, mulch materials and trench depth (cm) significantly ($P<0.05$) favoured high population of big black ants. The 100cm deep trenches mulched with palm frond recorded the highest (3.01) population of big black ants, followed by samples of 100cm trenches mulched with trash (2.65). All trenches mulched with saw dust had no big black ants. The interaction of trench depth and mulch materials scarcely habited big black ants.

Table 10 showed significant ($P<0.05$) influence of mulch materials on the populations of millipedes, termites and snails at three months after planting. The 60cm trenches mulched with trash and palm frond all recorded similar (0.67, 0.67) number of millipedes respectively, while trenches mulched with saw dust, wood shavings, black polythene and control plots were uninhabited by millipedes. Termite population was also significantly ($P<0.05$) decreased by trench depth. The 60cm trenches mulched with trash recorded the highest (13.70) populations of termites, closely followed by 80cm trenches mulched with palm frond (11.66). No termites were found in trenches mulched with saw dust and wood shavings (Table 10). The highest number of snails (1.00) was recorded in shallow 60cm trenches mulched with palm frond. Irrespective of the mulch sources, there were no snails recorded in all other trenches. There was no significant effect of interaction of trench depth (cm) and mulch materials on millipedes, termite and snail populations at two MAP (Table 10).

### 4.1.6 Soil temperature ($^0$C) under plantain

Soil temperature under late season plantain as affected by trench depth (cm) and mulch materials at one to four MAP (January – April 2011) is presented in Table 11. Trench depth had significant ($P<0.05$) influence on soil temperature in January, February and April 2011.

**Table 9: Effect of trench depth (cm) and mulch materials on the population of big black ant (*Doryllus nigiricans*),crickets (*Gryllus bimaculata*) and earth worms (*Eudrilus eygeniea*) in late season plantain at 3 months after planting (March, 2011).**

| Soil biological life | Big black ants | | | | Crickets | | | | Earth worms | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench | | | depth | | | (cm) | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 1.69 | 2.00 | 2.65 | 2.11 | 0.69 | 0.32 | 0.30 | 0.44 | 0.36 | 0.00 | 0.00 | 0.12 |
| Wood shaving | 0.65 | 0.67 | 1.35 | 0.89 | 0.35 | 0.33 | 0.31 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 1.68 | 1.66 | 3.01 | 2.12 | 0.33 | 0.35 | 0.36 | 0.34 | 0.36 | 0.37 | 0.00 | 0.24 |
| Saw dust | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.36 | 0.35 | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 1.00 | 1.34 | 1.32 | 1.22 | 0.66 | 0.30 | 0.00 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 |
| No mulch | 0.32 | 0.67 | 1.34 | 0.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.11 |
| Mean | 0.89 | 1.07 | 1.61 | 1.19 | 0.44 | 0.31 | 0.22 | 0.32 | 0.18 | 0.06 | 0.00 | 0.08 |
| LSD $_{(0.05)}$ Mulch | | | 0.79 | | | | ns | | | ns | | |
| LSD$_{(0.05)}$Trench depth | | | 0.56 | | | | ns | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | Ns | | | | ns | | | ns | | |

ns. = Not significant

**60=60x60x60cmdimension, 80cm=60x60x80cm dimension,100cm=60x60x100cm dimension**

**Table 10: Effect of trench depth (cm) and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemes bellicocus*) and snails (*Achatina fulica*) in late season plantain at 3 months after planting (March, 2011).**

| **Soil biological life** | **Millipedes** | | | | **Termites** | | | | **Snails** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench** | | | | **depth** | | | | **(cm)** | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 0.67 | 0.65 | 0.00 | 0.44 | 13.70 | 11.34 | 10.35 | 11.79 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wood shaving | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Palm frond | 0.67 | 0.35 | 0.33 | 0.45 | 11.30 | 11.66 | 9.02 | 10.66 | 1.00 | 0.68 | 0.00 | 0.56 |
| Saw dust | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black polythene | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.33 | 0.31 | 0.43 | 0.00 | 0.00 | 0.00 | 0.00 |
| No mulch | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 1.00 | 0.65 | 0.89 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mean | 0.22 | 0.16 | 0.05 | 0.15 | 4.45 | 4.06 | 3.39 | 3.96 | 0.17 | 0.11 | 0.00 | 0.09 |
| LSD $_{(0.05)}$ Mulch | | | 0.29 | | | | 0.99 | | | 0.26 | | |
| LSD$_{(0.05)}$ Trench depth | | | ns | | | | 0.70 | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | ns | | | | ns | | | ns | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm =60x60x100cm dimension**

**Table 11: Soil temperature ($^oC$) under late season plantain as affected by trench depth (cm) and mulch materials at 1-4 MAP (Jan-April, 2011).**

| Month after planting | January | | | | February | | | | March | | | | April | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench | | | | Depth | | | | (cm) | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 30.67 | 30.17 | 30.17 | 30.33 | 30.33 | 29.83 | 29.83 | 30.00 | 31.17 | 30.83 | 32.00 | 31.33 | 30.17 | 29.33 | 30.00 | 29.83 |
| Wood shaving | 31.50 | 31.33 | 30.33 | 31.00 | 31.17 | 30.67 | 30.17 | 30.67 | 31.67 | 30.83 | 31.17 | 31.22 | 31.00 | 30.00 | 30.33 | 30.44 |
| Palm frond | 31.33 | 29.50 | 29.67 | 30.17 | 30.17 | 29.50 | 29.50 | 30.06 | 31.83 | 32.17 | 30.83 | 31.61 | 31.50 | 31.00 | 30.17 | 30.89 |
| Saw dust | 30.00 | 28.67 | 30.83 | 29.83 | 30.00 | 28.67 | 30.33 | 29.67 | 32.00 | 31.00 | 32.33 | 31.78 | 31.00 | 30.67 | 30.67 | 30.78 |
| Black polythene | 31.00 | 30.50 | 30.00 | 30.50 | 30.50 | 29.50 | 29.50 | 29.83 | 31.00 | 31.00 | 30.50 | 30.83 | 30.00 | 30.00 | 30.00 | 30.00 |
| No mulch | 33.33 | 29.50 | 30.50 | 31.11 | 31.33 | 29.50 | 30.17 | 30.37 | 34.00 | 32.67 | 30.67 | 32.44 | 32.17 | 31.50 | 31.00 | 31.56 |
| Mean | 31.31 | 29.94 | 30.25 | 30.50 | 30.75 | 29.11 | 29.92 | 30.09 | 31.94 | 31.42 | 31.25 | 31.54 | 30.97 | 30.42 | 30.36 | 30.58 |
| LSD $_{(0.05)}$ Mulch | | | 0.95 | | | | ns | | | 0.99 | | | | 0.76 | | |
| LSD $_{(0.05)}$ Trench depth | | | 0.67 | | | | 0.75 | | | ns | | | | 0.54 | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | ns | | | | ns | | | ns | | | | ns | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm-60x60x80cm dimension, 100cm =60x60x100cm dimension**

(one, two and four MAP) respectively while application of different mulches had significant (P<0.05) influence on soil temperature at all stages of growth except at two MAP (February, 2011). The lowest soil temperature was recorded in 80cm trenches mulched with saw dust in January (28.67$^{o}$C) and February (28.67$^{o}$C) 2011 (one and two MAP) respectively.

The highest soil temperature was recorded in 60cm control (no mulch) plots in January (33.33$^{o}$C) February (31.33$^{o}$C), March (34.00$^{o}$C), and April (32.17$^{o}$C) 2011 (one to four MAP) respectively. The 100cm trenches mulched with black polythene recorded lowest soil temperature at three MAP (30.50$^{o}$C) (March 2011) followed by 100cm trenches mulched with palm frond (30.85$^{o}$C). At four MAP (April 2011), 80cm trenches mulched with trash recorded the lowest soil temperature (29.33$^{o}$C). The interaction of trench depth and mulch materials was not significant on soil temperature at any stage of growth (January to April 2011).

**4.1.7 Soil moisture content (%)**

**One to three months after planting (January – March 2011).**

The effect of trench depth (cm) and mulch materials on the mean moisture content (%) at 0-15cm of the various planting depths in late season plantain at the first three months after planting (MAP) is shown in Table 12. Soil moisture content (%) was significantly (P<0.05) influenced by mulch materials at one to two MAP, trench depth at one to three MAP, and their interactions at three MAP. The 100cm trenches mulched with black polythene recorded the highest moisture content (%) at one (20.12%), two (21.95%) and three (24.41%) MAP respectively. Lowest percentage soil moisture (7.13%, 8.83%) at one and two MAP was recorded in 60cm trenches of the control plots. However at three MAP, 80cm trenches of the control plots were most dry.

**Table 12: Effect of trench depth (cm) and mulch materials on the mean moisture content (%) at 0-15cm of the various planting depths in late season plantain at first 3 months after planting (January - March, 2011).**

| Month after planting | January | | | | February | | | | March | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench depth (cm) | | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 9.00 | 9.56 | 8.03 | 8.86 | 11.08 | 12.39 | 9.84 | 11.10 | 14.49 | 17.25 | 16.53 | 16.24 |
| Wood shaving | 7.92 | 11.29 | 9.53 | 9.58 | 9.84 | 11.47 | 13.65 | 11.65 | 15.42 | 20.40 | 18.60 | 18.14 |
| Palm frond | 9.00 | 11.00 | 9.40 | 9.80 | 11.14 | 13.25 | 11.52 | 11.97 | 17.21 | 19.10 | 20.48 | 18.93 |
| Saw dust | 10.08 | 10.41 | 9.37 | 9.95 | 11.98 | 12.39 | 11.19 | 11.85 | 15.18 | 17.70 | 21.16 | 18.01 |
| Black polythene | 9.21 | 11.83 | 20.12 | 12.68 | 12.36 | 14.08 | 21.95 | 16.13 | 15.11 | 22.32 | 24.41 | 20.61 |
| No mulch | 7.13 | 8.72 | 7.78 | 7.87 | 8.83 | 9.80 | 9.89 | 9.50 | 20.48 | 14.28 | 17.96 | 17.51 |
| Mean | 8.72 | 10.18 | 11.00 | 9.97 | 10.87 | 12.23 | 13.01 | 12.04 | 16.39 | 18.51 | 19.86 | 18.25 |
| LSD $_{(0.05)}$ Mulch | | 1.37 | | | | 1.72 | | | | ns | | |
| LSD $_{(0.05)}$ Trench depth | | 0.97 | | | | 1.22 | | | | 2.16 | | |
| LSD $_{(0.05)}$ mulch x trench depth | | ns | | | | ns | | | | 5.28 | | |

ns. = Not significant

**60= 60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm =60x60x100cm dimension**

The percentage soil moisture content at 15-30cm of the various planting depths in late season plantain at one to three MAP is shown in Table 13. Results indicated significant (P<0.05) effect of mulch materials at one and three MAP respectively. Trench depth (cm) did not significantly influence percentage soil moisture content at one, two and three MAP but the interaction of mulch materials and trench depth significantly (P<0.05) influenced soil moisture content at one and three MAP respectively. The 100cm trenches mulched with black polythene sheet recorded the highest percentage soil moisture content at one (11.25%), two (12.36%) MAP respectively while at three MAP, 80cm trenches mulched with trash recorded the highest (19.79%). The least percentage soil moisture content was recorded in 100cm trenches mulched with trash at one MAP (7.48%), 80cm trenches mulched with black polythene at two MAP (8.70%) and 100cm trenches mulched with trash at three MAP (9.90%), respectively.

### 4.1.8. Growth parameters of plantain

#### 4.8.1.1 Percentage sucker sprout

Table 14 showed that percentage sprout of late season plantain suckers was significantly (P<0.05) influenced by mulch materials and the interaction between trench depth and mulch materials at three MAP. All suckers planted in 80cm and 100cm in trenches mulched with black polythene sprouted (100%), while trenches 80cm depth mulched with wood shavings recorded 81.87% sucker sprout at three MAP respectively.With the exception of shallow trenches mulched with trash and palm frond, as well as all trenches in control plots, plantains in all other trenches recorded over 50% sucker spout at three MAP.

**Table 13: Effect of trench depth (cm) and mulch materials on the mean moisture content (%) at 15-30cm of the various planting depths in late season plantain at first three months after planting (January - March, 2011).**

| **Month after planting** | **January** | | | | **February** | | | | **March** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench** | | | | **depth** | | | | **(cm)** | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 7.83 | 8.45 | 7.48 | 7.92 | 9.43 | 10.25 | 9.49 | 9.73 | 12.78 | 19.79 | 14.08 | 13.22 |
| Wood shaving | 9.06 | 9.41 | 9.73 | 9.40 | 10.31 | 11.55 | 11.11 | 10.99 | 12.60 | 13.42 | 9.90 | 11.97 |
| Palm frond | 9.20 | 8.37 | 7.65 | 8.41 | 11.06 | 10.30 | 9.83 | 10.39 | 12.17 | 13.67 | 15.54 | 12.46 |
| Saw dust | 9.53 | 8.36 | 8.41 | 8.77 | 11.11 | 10.66 | 10.30 | 10.69 | 14.08 | 11.12 | 11.91 | 12.37 |
| Black polythene | 10.28 | 7.89 | 11.25 | 9.81 | 12.36 | 8.70 | 12.36 | 11.14 | 10.95 | 11.11 | 12.78 | 11.06 |
| No mulch | 8.70 | 9.27 | 8.31 | 8.78 | 10.33 | 11.10 | 9.90 | 10.44 | 13.00 | 11.91 | 11.11 | 12.56 |
| Mean | 9.10 | 8.63 | 8.80 | 8.84 | 10.77 | 10.43 | 10.50 | 10.56 | 12.60 | 12.34 | 12.39 | 12.44 |
| LSD $_{(0.05)}$ Mulch | 1.02 | | | | ns | | | | 1.51 | | | |
| LSD $_{(0.05)}$ Trench depth | ns | | | | ns | | | | ns | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | 1.76 | | | | 1.92 | | | | ns | | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm-60x60x80cm dimension, 100cm =60x60x100cm dimension**

**Table 14: Effect of trench depth (cm) and mulch materials on the percentage sucker spout of late season plantain at 4 months after planting**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch sources** | **60** | **80** | **100** | **Mean** |
| Trash | 48.11 | 70.50 | 50.30 | 56.30 |
| Wood shaving | 70.50 | 81.87 | 70.67 | 74.34 |
| Palm frond | 49.44 | 50.32 | 80.62 | 60.12 |
| Saw dust | 81.60 | 70.60 | 59.40 | 70.53 |
| Black polythene | 50.33 | 100.00 | 100.00 | 83.44 |
| No mulch | 46.30 | 49.31 | 38.43 | 44.68 |
| Mean | 63.21 | 70.43 | 66.57 | 67.24 |

LSD $_{(0.05)}$ Mulch 19.15

LSD $_{(0.05)}$ Trench depth ns

LSD $_{(0.05)}$ Mulch x trench depth 33.56

ns. = Not significant

**60=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm =60x60x100cm dimension.**

#### 4.1.8.2 Plantain pseudostem height (cm)

Plantain pseudostem height (cm) as affected by trench depth, mulch materials and their interaction at six, nine MAP and at harvest is shown in Table 15. There was a significant (P <0.05) effect of trench depth and mulch materials on plantain pseudosterm height at six MAP but the interaction between trench depth and mulch materials was not significant. At nine MAP, neither trench depth, nor mulch materials nor their interaction significantly affected plantain pseudostem height. However at harvest the pseudostem height of plantain was significantly (P <0.05) affected by mulch materials. Plantains in 100cm trenches and mulched with trash recorded the tallest plants (137.30cm) at six MAP while those in 80cm trenches mulched with wood shavings recorded tallest plants at harvest (250.00cm). Plantains in control plots of 80cm depth produced shortest plants at six (71.70cm), nine (109.80cm) MAP and at harvest (202.70cm), respectively.

#### 4.1.8.3 Plantain pseudostem girth (cm)

The pesudostem girth (cm) of late season plantain (Table 16) significantly (P <0.05) increased due to mulch materials at six, nine MAP and at harvest, respectively. Trench depth and the interaction between trench depth and mulch materials had similar effect on plantain pseudostem girth at six and nine MAP respectively. However, the interaction between trench depth and mulch materials significantly (P <0.05) influenced plantain pseudostem girth at harvest. Plantains established in 60cm plots and mulched with trash recorded the biggest girth at six MAP (39.10cm), while those planted in 80cm trenches and mulched with wood shavings recorded the biggest girth at nine MAP (54.00cm). Biggest pseudostem girth at harvest (64.17cm) was recorded in plantains in 60cm trenches mulched with saw dust. Smallest pseudostem girth was obtained from plantains in 80cm control plots at six (20.33cm) and nine (29.40cm) MAP respectively and those in

**Table 15: Effect of trench depth (cm) and mulch materials on the pseudostem height (cm) of late season plantain at 6, 9 MAP and at harvest.**

| Month after planting 6 | | | | | 9 | | | | Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Trench | | | depth | | | | (cm) | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 131.20 | 109.70 | 137.30 | 126.10 | 160.30 | 139.50 | 156.00 | 151.90 | 243.90 | 234.10 | 239.60 | 239.20 |
| Wood shaving | 121.00 | 131.50 | 127.80 | 126.80 | 156.70 | 173.50 | 152.70 | 160.90 | 242.80 | 250.00 | 239.30 | 244.00 |
| Palm frond | 104.30 | 112.40 | 124.90 | 113.90 | 135.50 | 159.90 | 120.00 | 138.50 | 226.50 | 240.60 | 242.70 | 232.80 |
| Saw dust | 99.50 | 109.70 | 112.30 | 107.20 | 160.80 | 133.40 | 140.50 | 144.90 | 249.00 | 219.30 | 230.00 | 232.80 |
| Black polythene | 109.10 | 114.70 | 116.30 | 113.30 | 142.00 | 127.00 | 135.80 | 134.90 | 225.00 | 204.10 | 212.70 | 213.90 |
| No mulch | 89.50 | 71.70 | 115.20 | 92.10 | 119.30 | 109.80 | 140.00 | 123.00 | 206.00 | 202.70 | 222.00 | 210.20 |
| Mean | 109.10 | 108.30 | 122.30 | 113.20 | 145.70 | 140.50 | 140.80 | 142.40 | 232.20 | 225.10 | 231.10 | 229.50 |
| LSD $_{(0.05)}$ Mulch | | | 15.89 | | | | ns | | | 13.52 | | |
| LSD $_{(0.05)}$ Trench depth | | | 11.23 | | | | ns | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | ns | | | | ns | | | ns | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm=60x60x80cm dimension, 100=60x60x100cm dimension**

**Table 16: Effect of trench depth (cm) and mulch materials on the pseudostem girth(cm) of late season plantain at 6, and 9 MAP and at harvest.**

| Month after planting | 6 | | | | 9 | | | | Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench | | | | depth | | | | (cm) | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 39.10 | 29.00 | 36.33 | 34.81 | 47.00 | 41.67 | 46.70 | 45.14 | 58.27 | 53.00 | 60.27 | 57.18 |
| Wood shaving | 34.92 | 36.25 | 33.47 | 34.88 | 47.33 | 54.00 | 42.60 | 47.98 | 60.86 | 62.69 | 56.63 | 59.91 |
| Palm frond | 33.00 | 34.00 | 32.33 | 33.11 | 42.67 | 49.00 | 48.30 | 46.64 | 54.60 | 62.23 | 58.50 | 58.60 |
| Saw dust | 29.39 | 30.65 | 28.63 | 29.50 | 43.83 | 44.83 | 47.23 | 45.30 | 64.17 | 54.83 | 61.13 | 60.04 |
| Black polythene | 29.07 | 30.17 | 29.33 | 29.52 | 41.77 | 36.50 | 39.67 | 39.31 | 58.37 | 43.32 | 47.83 | 49.84 |
| No mulch | 26.20 | 20.33 | 28.50 | 25.01 | 37.75 | 29.40 | 41.50 | 36.20 | 51.60 | 44.60 | 50.37 | 48.86 |
| Mean | 31.95 | 30.07 | 31.43 | 31.15 | 43.40 | 42.60 | 44.30 | 43.40 | 57.96 | 53.45 | 55.79 | 55.74 |
| LSD $_{(0.05)}$ Mulch | 5.26 | | | | 7.47 | | | | 5.15 | | | |
| LSD $_{(0.05)}$ Trench depth | ns | | | | ns | | | | ns | | | |
| LSD $_{(0.05)}$ mulch x trench depth | ns | | | | ns | | | | 8.93 | | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm-60x60x80cm dimension, 100cm =60x60x100cm dimension**

80cm plots mulched with black polythene at harvest (43.32).

### 4.1.8.4 Number of leaves

The number of leaves in late season plantain (Table 17) at six, nine MAP and at harvest indicated highly significant (P<0.05) difference due to application of different mulches at all stages of growth. The highest mean number of plantain leaves was recorded in 80cm trenches mulched with palm frond at six MAP (14.00), 80cm trenches mulched with wood shavings at nine MAP (9.00) and at harvest (7.83) respectively. Least number of leaves was recorded in 80cm control plots at six MAP (10.33), 80cm plots mulched with black polythene at nine MAP (4.43) and 100cm plots mulched with same at harvest (4.50) respectively. Mean number of leaves was not significantly influenced by trench depth and the interaction of trench depth and mulch materials at six MAP and at harvest respectively, but at nine MAP there was a significant (P<0.05) decrease in the number of leaves in late season plantain due to interaction of trench depth and mulch materials.

### 4.1.8.5 Leaf area ($cm^2$)

At six, nine MAP and harvest respectively, the leaf area (LA) (cm) (Table 18) differed significantly (P<0.05) due to mulch materials. Trench depth was not significant on LA at any stage of growth but the interaction of trench depth and mulch materials was significant (P <0.05) at harvest only. Broadest plantain leaf area (LA) was recorded in plantains in 100cm trenches mulched with trash at six MAP (5678.99$cm^2$), 80cm trenches mulched with wood shavings at nine MAP (9692.80$cm^2$) and harvest (9621.15$cm^2$) respectively. Narrowest plantain leaf area was recorded in plantains in trenches of 80cm control plots at six MAP (2970.16$cm^2$), nine MAP (3698.05$cm^2$) and 80cm trenches mulched with black polythene (2352.00$cm^2$) at harvest respectively. Generally, medium trenches (80cm) produced narrowest leaves at six, nine MAP and harvest, excluding those treated with wood shavings which produced broadest leaves at nine MAP and at harvest, those mulched with black polythene at six MAP and palm frond at nine MAP respectively.

**Table 17: Effect of trench depth (cm) and mulch materials on the number of leaves in late season plantain at 6, and 9 MAP and at harvest.**

| **Month after planting** | **6** | | | | **9** | | | | **Harvest** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 13.00 | 12.67 | 13.67 | 13.11 | 5.17 | 5.67 | 4.50 | 5.11 | 7.10 | 7.00 | 7.07 | 7.06 |
| Wood shaving | 11.83 | 12.50 | 11.67 | 12.00 | 6.50 | 9.00 | 5.50 | 7.00 | 5.83 | 7.83 | 5.50 | 6.39 |
| Palm frond | 13.83 | 14.00 | 12.00 | 13.28 | 5.43 | 7.00 | 6.25 | 6.23 | 7.00 | 6.84 | 5.75 | 6.53 |
| Saw dust | 11.72 | 12.27 | 12.83 | 12.27 | 8.32 | 5.77 | 6.50 | 5.86 | 6.17 | 5.90 | 5.90 | 5.99 |
| Black polythene | 11.00 | 11.43 | 11.00 | 11.14 | 6.00 | 4.43 | 5.33 | 4.26 | 5.50 | 4.83 | 4.50 | 4.94 |
| No mulch | 12.17 | 10.33 | 12.50 | 11.67 | 6.17 | 6.33 | 5.50 | 6.00 | 5.17 | 4.92 | 4.59 | 5.00 |
| Mean | 12.16 | 12.20 | 12.28 | 12.25 | 6.26 | 6.37 | 5.60 | 6.08 | 6.13 | 6.22 | 5.52 | 5.98 |
| $LSD_{(0.05)}$ Mulch | 0.99 | | | | 1.00 | | | | 0.86 | | | |
| $LSD_{(0.05)}$ Trench depth | ns | | | | ns | | | | ns | | | |
| $LSD_{(0.05)}$ mulch x trench depth | ns | | | | 1.73 | | | | ns | | | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 18: Effect of trench depth (cm) and mulch materials on the leaf area (LA) ($cm^2$) of late season plantain at 6 and 9 MAP and at harvest.**

| **Month after planting** | **6** | | | | **9** | | | | **Harvest** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Trench** | | | **depth** | | | **(cm)** | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 5349.12 | 4438.07 | 5678.99 | 5155.39 | 5943.28 | 5316.97 | 5545.23 | 5601.83 | 5752.89 | 4455.35 | 5119.68 | 5109.29 |
| Wood shaving | 5172.19 | 5600.60 | 5024.71 | 5265.83 | 6515.13 | 9692.80 | 5551.98 | 7253.30 | 7120.74 | 9621.15 | 5155.69 | 7299.20 |
| Palm frond | 4466.24 | 3900.12 | 5338.44 | 5686.27 | 4732.00 | 5801.64 | 6128.50 | 5554.05 | 3453.40 | 5645.20 | 5155.50 | 4751.37 |
| Saw dust | 4330.31 | 3315.19 | 4249.78 | 3965.10 | 7245.00 | 4920.96 | 5284.49 | 5814.32 | 5910.44 | 4269.45 | 5791.88 | 5323.92 |
| Black polythene | 4380.00 | 4535.65 | 4345.91 | 4420.52 | 6270.43 | 4765.09 | 4967.95 | 5334.49 | 4520.71 | 2352.00 | 3816.40 | 3563.04 |
| No mulch | 3333.49 | 2970.16 | 4540.80 | 3614.52 | 4635.62 | 3698.05 | 5391.92 | 4575.20 | 3745.57 | 3134.33 | 5211.66 | 4030.52 |
| Mean | 4505.23 | 4126.63 | 4863.11 | 4498.82 | 5888.99 | 5699.25 | 5478.35 | 5680.86 | 5083.96 | 4912.91 | 5041.79 | 5012.18 |
| $LSD_{(0.05)}$ Mulch | | | 1115.701 | | | | 1459.76 | | | | 1533.07 | |
| $LSD_{(0.05)}$ Trench depth | | | ns | | | | ns | | | | ns | |
| $LSD_{(0.05)}$ mulch x trench depth | | | ns | | | | ns | | | | 2635.34 | |

ns. = Not significant

**60=60x60x60cm dimension, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**4.18.6 Leaf area index (LAI)**

The effect of trench depth (cm) and mulch materials on the leaf area index (LAI) of late season plantain is presented in Table 19. Results follow the same trend with the leaf area, indicating highly significant (P <0.05) difference between treatments due to application of different mulches at all growth stages. There was no significant effect of trench depth at any stage of growth but interaction of trench depth and mulch materials significantly (P <0.05) affected LAI of plantain at harvest only. Broadest LAI was recorded in plantain in 100cm trenches mulched with trash at six MAP (3.79) plantain treated with wood shavings in 80cm trenches at nine MAP (6.46) and at harvest (6.41) respectively. Narrowest leaf area index was recorded in plantains in 80cm controls plots at six (1.98) and nine (2.460) MAP respectively, and in plantains treated with black polythene in 80cm plots at harvest (1.58).

**4.1.8.7 Number of suckers**

The effect of trench depth (cm) and mulch sources on the number of suckers produced in late season plantain at six, nine MAP and at harvest (Table 20) showed significant (P<0.05) differences due to mulch materials at each stage of growth. There were no significant differences due to trench depth and the interaction of trench depth and mulch materials at nine MAP and at harvest respectively. However, the interaction was significant (P<0.05) on sucker proliferation of late season plantain at six MAP. Plantains in 80cm trenches mulched with wood shavings proliferated the greatest number of suckers at six (7.00), nine (7.00) MAP and at harvest (8.00) respectively. All plots mulched with black polythene produced no suckers at 6MAP. This trend was also observed in 60cm plots mulched with palm frond and control (manured but unmulched) plots of 60 and 80cm depths. At nine MAP 80cm trenches mulched with black polythene recorded no suckers (0.0), while 60cm trenches mulched with same produced no suckers at harvest.

**Table 19: Effect of trench depth (cm) and mulch materials on the leaf area index (LAI) of late season plantain at 6 and 9 MAP and at harvest.**

| Month after planting | 6 | | | | 9 | | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench depth (cm) | | | | | | | | | | |
| **Mulch source** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** |
| Trash | 3.57 | 2.96 | 3.79 | 3.44 | 3.89 | 3.54 | 3.70 | 3.71 | 3.84 | 2.97 | 3.41 |
| Wood shaving | 3.45 | 3.72 | 3.40 | 3.53 | 4.44 | 6.46 | 3.70 | 4.87 | 4.44 | 6.41 | 3.70 |
| Palm frond | 2.98 | 3.12 | 3.56 | 3.22 | 3.15 | 4.08 | 4.09 | 3.77 | 2.30 | 3.64 | 3.43 |
| Saw dust | 2.89 | 2.21 | 1.78 | 2.29 | 4.83 | 4.63 | 3.52 | 4.33 | 3.94 | 2.84 | 3.86 |
| Black polythene | 2.72 | 3.02 | 2.91 | 2.88 | 4.18 | 3.19 | 3.31 | 3.56 | 3.01 | 1.58 | 2.54 |
| No mulch | 2.09 | 1.98 | 3.03 | 2.37 | 3.10 | 2.46 | 3.59 | 3.05 | 2.50 | 2.09 | 3.37 |
| Mean | 2.95 | 2.84 | 3.08 | 2.95 | 3.93 | 4.06 | 3.65 | 3.86 | 3.39 | 3.26 | 3.85 |
| LSD $_{(0.05)}$ Mulch | 0.80 | | | | 1.02 | | | | 1.02 | | |
| LSD $_{(0.05)}$ Trench depth | ns | | | | ns | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | ns | | | | ns | | | | 0.18 | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 20: Effect of trench depth (cm) and mulch materials on the number of suckers produced in late season plantain at 6 , 9 MAP and at harvest.**

| **Month after planting** | **6** | | | | **9** | | | | **Harvest** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench** | | | | **depth** | | | | **(cm)** | | | |
| Mulch source | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 2.67 | 0.43 | 2.00 | 1.70 | 3.33 | 3.00 | 3.33 | 3.22 | 4.75 | 4.17 | 3.50 | 4.14 |
| Wood shaving | 1.00 | 3.50 | 1.83 | 2.11 | 3.17 | 7.00 | 2.00 | 4.06 | 4.50 | 8.00 | 3.75 | 5.42 |
| Palm frond | 0.00 | 0.56 | 1.06 | 0.54 | 2.00 | 2.43 | 3.10 | 2.51 | 4.00 | 4.51 | 5.00 | 4.50 |
| Saw dust | 1.00 | 2.50 | 0.00 | 1.17 | 2.80 | 3.00 | 2.67 | 2.82 | 5.00 | 3.50 | 4.60 | 4.37 |
| Black polythene | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.67 | 0.56 | 0.00 | 1.33 | 0.67 | 0.67 |
| No mulch | 0.00 | 0.00 | 0.33 | 0.11 | 1.33 | 0.33 | 1.50 | 1.06 | 2.58 | 2.50 | 3.58 | 2.78 |
| Mean | 0.78 | 1.17 | 0.87 | 0.94 | 2.27 | 2.63 | 2.21 | 2.27 | 3.47 | 4.00 | 3.46 | 3.65 |
| LSD $_{(0.05)}$ Mulch | | 0.87 | | | | 1.76 | | | | 1.99 | | |
| LSD $_{(0.05)}$ Trench depth | | ns | | | | ns | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | 1.50 | | | | ns | | | | ns | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

### 4.1.9 Plantain crop protection

#### 4.1.9.1 Black sigatoka leaf spot disease of plantain

The response of late season plantain to Black Sigatoka leaf spot disease following different trench depths and application of different mulches at six, nine MAP and at harvest (Table 21) showed that there was no infection at six MAP. At nine MAP, trench depth, mulch materials and their interaction significantly ($P<0.05$) influenced plantain response to Black Sigatoka leaf spot disease. However, trench depth, mulch materials and their interaction had no significant effect on plantains response to Black Sigatoka leaf spot disease at harvest. The highest plantain Black Sigatoka severity (3.00) was recorded in plantains mulched with palm frond in 60cm trenches at nine MAP while 60cm trenches mulched with trash produced plantains which recorded the least disease severity (1.00).

#### 4.1.9.2 Plantain leaf damage by *Zonocerus variegatus*

The response of late season plantain to leaf damage caused by *Zonocerus variegatus* is presented in Table 22. At six and nine MAP, there was no leaf damage but at harvest trench depth (cm) and the interaction of trench depth and mulch materials was not significant on leaf damage by Zonocerus. However, mulch application significantly ($P<0.05$) affected response of plantain to leaf damage caused by *Zonocerus variegatus* at harvest. The highest seventy at harvest was recorded in plantains in all trenches mulched with black polythene (2.0) and 80cm trenches of control plots (2.0) while plantains in medium trenches treated with trash and shallow trenches treated with saw dust recorded no leaf damage by *Zonocerus variegatus* (1.00).

**Table 21: Effect of trench depth (cm) and mulch materials on the severity of black Sigatoka disease of late season plantain at 6 , 9 MAP and at harvest.**

| Month after planting | 6 | | | | 9 | | | | Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench | | | | depth | | | | (cm) | | | |
| | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Mulch source | | | | | | | | | | | | |
| Trash | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 2.00 | 2.00 | 1.67 | 0.67 | 0.67 | 1.00 | 0.78 |
| Wood shaving | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 2.00 | 2.00 | 1.89 | 0.67 | 0.67 | 0.83 | 0.72 |
| Palm frond | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 2.00 | 2.50 | 2.50 | 1.00 | 1.50 | 1.33 | 1.28 |
| Saw dust | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 2.00 | 2.67 | 2.06 | 0.67 | 1.33 | 1.00 | 1.00 |
| Black polythene | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 1.67 | 1.89 | 0.67 | 0.67 | 0.67 | 0.67 |
| No mulch | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 2.00 | 1.89 | 1.50 | 1.50 | 1.00 | 1.33 |
| Mean | 0.00 | 0.00 | 0.00 | 0.00 | 1.86 | 2.00 | 2.14 | 2.00 | 0.86 | 1.06 | 0.97 | 0.96 |
| $LSD_{(0.05)}$ Mulch | | | | | | 0.75 | | | | ns | | |
| $LSD_{(0.05)}$ Trench depth | | | | | | 0.53 | | | | ns | | |
| $LSD_{(0.05)}$ Mulch x trench depth | | | | | | 1.30 | | | | ns | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 22: Effect of trench depth (cm) and mulch materials on late season plantain leaf damage by *Zonocerus variagatus* at 6, 9 MAP and at harvest.**

| **Month after planting** | **6** | | | | **9** | | | | **Harvest** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| Mulch source | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.33 | 1.00 | 1.33 | 1.22 |
| Wood shaving | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.67 | 1.67 | 1.67 | 1.67 |
| Palm frond | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.67 | 1.67 | 1.67 | 1.67 |
| Saw dust | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.33 | 1.33 | 1.22 |
| Black polythene | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| No mulch | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.67 | 2.00 | 1.67 | 1.78 |
| Mean | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.56 | 1.61 | 1.61 | 1.59 |
| LSD $_{(0.05)}$ Mulch | | | ns | | | ns | | | | 0.48 | | |
| LSD $_{(0.05)}$ Trench depth | | | ns | | | ns | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | ns | | | ns | | | | ns | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

#### 4.1.9.3 Weed dry weight (kg $ha^{-1}$)

Table 23 shows the effect of trench depth (cm) mulch materials and their interaction on the weed dry weight (kg $ha^{-1}$) in late season plant and first ratoon plantain. No significant differences were observed due to trench depth at any stage of growth. Mulch materials and the interaction of trench depth and mulch materials were significant ($P<0.05$) on weed dry weight (t $ha^{-1}$) at all stages of growth. The greatest weed dry weight at six MAP (135.47 kg $ha^{-1}$) was recorded in control plots of 80cm dimension closely followed by deepest trenches of 100cm mulched with saw dust (134.59 kg $ha^{-1}$). The least weed dry weight (110.04 kg $ha^{-1}$) was recorded in 80cm trenches treated with wood shavings at six MAP. At nine MAP and harvest respectively, 80cm trenches mulched with wood shavings recorded the least weed dry weight (98.35 kg $ha^{-1}$and 70.33 kg $ha^{-1}$) while 60cm control plots produced the greatest weed dry weight (122.49 kg $ha^{-1}$) at nine MAP. At harvest 80cm trenches of control plots recorded the highest weed dry weight (93.33 kg $ha^{-1}$) closely followed by black polythene mulched plots of same dimension(93.04 kg $ha^{-1}$) (Table 23).

### 4.1.10 Reproductive and yield parameters of plant crop plantain

#### 4.1.10.1 Days to 50% flowering

The number of days to 50% flowering in late season plantain (Table 24) showed highly significant ($P<0.05$) influence of mulch materials, trench depth ($P<0.05$) and their interaction ($P<0.05$). The highest number of days to 50% flowering in late season plantain was recorded in plantains mulched with black polythene in100cm trenches (594.40 days) followed by those in control (no mulch) plots of 60cm (593.70 days). Least number of days to 50% flowering was recorded in plantains mulched with wood shavings in 80cm trenches (308.80 days) followed by those in 60cm trenches mulched with same (372.60 days).

**Table 23: Effect of trench depth (cm) and mulch materials on weed dry weight (kg $ha^{-1}$) of late season plantain at 6 , 9 MAP and at harvest.**

| **Month after planting** | **6** | | | | **9** | | | | **Harvest** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| Mulch source | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 219.65 | 125.90 | 128.98 | 128.18 | 98.63 | 102.64 | 97.59 | 99.62 | 76.69 | 81.27 | 73.85 | 77.27 |
| Wood shaving | 131.15 | 110.04 | 121.47 | 120.88 | 113.75 | 98.35 | 106.80 | 106.31 | 89.55 | 70.33 | 78.31 | 79.39 |
| Palm frond | 115.05 | 127.70 | 115.08 | 119.29 | 106.19 | 107.24 | 101.61 | 105.01 | 83.53 | 82.16 | 76.77 | 80.87 |
| Saw dust | 110.98 | 132.79 | 134.59 | 126.12 | 96.05 | 122.16 | 120.75 | 112.99 | 72.32 | 92.27 | 89.00 | 83.86 |
| Black polythene | 129.90 | 134.16 | 123.30 | 129.12 | 113.26 | 123.62 | 119.03 | 118.63 | 88.25 | 93.04 | 89.55 | 88.51 |
| No mulch | 132.79 | 135.47 | 128.47 | 131.31 | 122.49 | 110.73 | 111.07 | 114.76 | 87.51 | 93.33 | 88.37 | 89.64 |
| Mean | 125.95 | 127.15 | 125.31 | 126.14 | 108.39 | 110.79 | 109.48 | 109.55 | 82.98 | 84.32 | 82.31 | 83.20 |
| LSD $_{(0.05)}$ Mulch | 4.44 | | | | 4.13 | | | | 2.73 | | | |
| LSD $_{(0.05)}$ Trench depth | ns | | | | ns | | | | ns | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | 7.69 | | | | 7.15 | | | | 6.69 | | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 24: Effect of trench depth (cm) and mulch materials on the number of days to 50% flowering in late season plantain.**

| | **Trench** | **depth** | **(cm)** | |
|---|---|---|---|---|
| **Mulch sources** | **60** | **80** | **100** | **Mean** |
| Trash | 410.80 | 418.60 | 435.50 | 421.60 |
| Wood shaving | 372.60 | 308.80 | 522.70 | 401.40 |
| Palm frond | 591.60 | 520.50 | 533.50 | 501.90 |
| Saw dust | 435.70 | 526.00 | 544.00 | 501.90 |
| Black polythene | 570.10 | 497.40 | 594.40 | 553.60 |
| No mulch | 533.30 | 553.20 | 593.70 | 566.10 |
| Mean | 489.50 | 470.80 | 536.80 | 499.00 |
| LSD($_{0.05}$) Mulch | 24.87 | | | |
| LSD $_{(0.05)}$ Trench depth | 17.58 | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | 43.07 | | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

#### 4.1.10.2 Bunch yield of plantain at harvest (t $ha^{-1}$)

Table 25 indicates that there was a significant ($P<0.05$) effect of mulch materials, trench depth ($P<0.05$), and their interaction ($P<0.05$) on the bunch yield (t $ha^{-1}$) of late season plantain at harvest. The highest plantain yield (20.88 t $ha^{-1}$) was recorded in plantains in 80cm trenches mulched with wood shavings, followed by 60cm trenches mulched with saw dust (16.72 t $ha^{-1}$). However, plantains in control plots of 60cm, 80cm and 100cm dimensions recorded the lowest yield (13.24 t $ha^{-1}$, 13.53 t $ha^{-1}$ and 13.03 t $ha^{-1}$) respectively.

#### 4.1.10.3 Number of hands per bunch at harvest

The number of hands per bunch of late season plantain at harvest (Table 26) indicated significant ($P<0.05$) effect of mulch materials and trench depth (cm) ($P<0.05$). Plantains mulched with wood shavings in 80cm trenches recorded the highest number of hands per bunch (7.10) while those in control plots of 100cm dimension recorded the least number of hands per bunch (4.36). The interaction of trench depth and mulch materials was not significant on the number of hands per bunch of late season plantain at harvest.

#### 4.1.10.4 Number of fingers per bunch at harvest

The number of fingers per bunch in late season plantain is presented in Table 27. Results indicate significant ($P<0.05$) effect of trench depth, mulch materials ($P<0.05$) and their interaction ($P<0.05$). Plantains in medium (80cm) trenches mulched with wood shavings recorded the highest number of fingers per bunch (47.84) at harvest while plantains in deep (100cm) control plots recorded the least number of fingers per bunch (15.65) at harvest. In all treatments except in palm frond mulched trenches, shallow (60cm) and medium (80cm) trenches recorded greater number of fingers/bunch than in deep trenches (60cm).

**Table 25: Effect of trench depth (cm) and mulch materials on the bunch yield t $ha^{-1}$ of late season plantain plant crop at harvest.**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch sources** | **60** | **80** | **100** | **Mean** |
| Trash | 14.91 | 14.55 | 13.95 | 14.47 |
| Wood shaving | 15.59 | 20.88 | 14.70 | 16.95 |
| Palm frond | 13.97 | 14.77 | 13.98 | 14.24 |
| Saw dust | 16.72 | 14.64 | 13.93 | 15.09 |
| Black polythene | 14.10 | 14.70 | 13.92 | 14.24 |
| No mulch | 13.24 | 13.53 | 13.03 | 13.27 |
| Mean | 14.71 | 15.52 | 13.92 | 14.72 |
| LSD $_{(0.05)}$ Mulch | 0.69 | | | |
| LSD $_{(0.05)}$ Trench depth | 0.48 | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | 1.19 | | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 26: Effect of trench depth (cm) and mulch materials on the number of hands per bunch in late season plantain at harvest.**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch source** | **60** | **80** | **100** | **Mean** |
| Trash | 5.88 | 5.68 | 4.62 | 5.39 |
| Wood shavings | 6.28 | 7.10 | 6.06 | 6.48 |
| Palm frond | 5.09 | 6.37 | 6.02 | 5.83 |
| Saw dust | 5.59 | 5.95 | 5.24 | 5.59 |
| Black polythene | 4.85 | 5.79 | 4.81 | 5.15 |
| No mulch | 4.73 | 5.25 | 4.36 | 4.78 |
| Mean | 5.41 | 6.02 | 5.18 | 5.38 |
| | | | | |
| LSD $_{(0.05)}$ Mulch | | 0.50 | | |
| LSD $_{(0.05)}$ Trench depth | | 0.35 | | |
| LSD $_{(0.05)}$ Mulch x Trench depth | | ns | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

**Table 27: Effect of trench depth (cm) and mulch materials on the number of fingers/bunch in late season plantain at harvest.**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| | **60** | **80** | **100** | **Mean** |
| **Trash** | 38.54 | 34.55 | 25.75 | 31.95 |
| **Wood shaving** | 40.06 | 47.84 | 39.34 | 41.41 |
| **Palm frond** | 28.79 | 39.90 | 35.91 | 35.87 |
| **Saw dust** | 39.44 | 37.75 | 35.61 | 35.61 |
| **Black polythene** | 26.13 | 27.82 | 20.19 | 24.72 |
| **No mulch** | 22.16 | 27.28 | 15.65 | 20.03 |
| **Mean** | 32.52 | 35.86 | 27.01 | 31.80 |
| LSD $_{(0.05)}$ Mulch | 3.36 | | | |
| LSD $_{(0.05)}$ Trench depth | 2.38 | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | 5.83 | | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

### 4.1.11 Growth parameters for first ratoon crop of late season plantain

#### 4.1.11.1 Pseudostem height (cm), girth (cm) and number of leaves at harvest

The growth parameters pseudostem height (cm), girth (cm) and number of leaves of first ratoon crop in late season plantain (Table 28) at harvest indicates highly significant ($P<0.05$) difference in all parameters due to application of different mulches and the interactions of trench depth (cm) and mulch materials ($P<0.05$). Although the pseudostem height (cm), girth (cm) and number of leaves were not significantly influenced by trench depth (cm) late season plantain first ratoon crops, plantains in deepest trenches (100cm) mulched with trash and palm frond seemed to perform slightly better than those planted in shallow trenches (60cm).

The tallest first ratoon crops were produced in 80cm plots mulched with wood shavings (237.30cm), followed by plantains in 60cm plots mulched with saw dust (228.60cm) and those in 100cm plots mulched with trash (224.60cm) and palm frond (223.40cm) respectively. The shortest first ratoon crops were produced in control plots of 80cm trenches (71.00cm), while those in 100cm plots and 60cm plots mulched with black polythene had no ratoon crops hence they had 0.0 values at harvest respectively (Table 28) in all growth parameters. The first ratoon crops in 80cm in trenches mulched with wood shavings recorded the largest pseudostem girth (62.90cm) and number of leaves (8.17) respectively while control plots of 80cm dimension produced the thinnest first ratoon crops (16.80cm) and least number of leaves (1.87) at harvest (Table 28).

**Table 28: Effect of trench depth (cm) and mulch materials on pseudostem height (cm), girth (cm) and number of leaves in first ratoon crop of late season plantain at harvest.**

| Growth parameters at harvest | Height | | | | Girth | | | | Leaves | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trench | | | | depth | | | | (cm) | | | |
| Mulch source | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 220.90 | 219.60 | 224.60 | 221.70 | 56.70 | 52.90 | 59.00 | 56.20 | 7.67 | 7.57 | 7.67 | 7.63 |
| Wood shaving | 222.90 | 237.30 | 218.70 | 226.30 | 60.90 | 62.90 | 55.50 | 59.10 | 6.44 | 8.17 | 6.17 | 6.93 |
| Palm frond | 208.20 | 220.60 | 223.40 | 217.40 | 53.90 | 60.90 | 56.40 | 57.80 | 7.83 | 7.35 | 6.11 | 7.10 |
| Saw dust | 228.60 | 204.00 | 209.10 | 213.90 | 60.20 | 53.80 | 57.20 | 57.10 | 6.50 | 5.90 | 5.17 | 5.86 |
| Black polythene | 0.00 | 130.90 | 0.00 | 43.60 | 0.00 | 34.30 | 0.00 | 11.40 | 0.00 | 3.33 | 0.00 | 1.11 |
| No mulch | 187.10 | 71.00 | 201.70 | 153.30 | 50.70 | 16.80 | 49.70 | 39.00 | 5.50 | 1.67 | 5.58 | 4.25 |
| Mean | 178.00 | 180.60 | 179.60 | 179.40 | 47.10 | 46.90 | 46.30 | 46.80 | 5.66 | 5.66 | 5.12 | 5.48 |
| LSD $_{(0.05)}$ Mulch | | | 38.46 | | | 10.26 | | | | 1.16 | | |
| LSD $_{(0.05)}$ Trench depth | | | ns | | | Nn | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | 66.62 | | | 17.77 | | | | 2.02 | | |

ns. = Not significant

**60=60x60x60cm, 80cm=60x60x80cm dimension, 100= 60x60x100cm dimension**

#### 4.1.11.2 Number of suckers, LA ($cm^2$) and LAI of first ratoon crop of late season plantain at harvest.

Sucker production, leaf area (LA) and leaf area index (LAI) of first ratoon crop of late season plantain at harvest (Table 29) shows no significant difference among treatment means due to trench depth and the interaction of trench depth and mulch materials on sucker proliferation. Late season plantain first ratoon crops responded significantly ($P<0.05$) to application of different mulches. The highest number of suckers (8.17) at harvest was recorded in first ratoon crops mulched with wood shavings in medium (80cm depth) plots, closely followed by crops in 60cm plots mulched with saw dust (6.00). Least number of suckers (0.00, 0.55) was produced in shallow and deep trenches mulched with black polythene.

Mulch materials and the interaction of mulch materials and trench depth had significant ($P<0.05$) influence on LA and LAI at harvest. The broadest leaf area (LA) ($cm^2$) and leaf area index (LAI) was recorded in first ratoon crops mulched with wood shavings in 80cm plots (7908.00$cm^2$ and 4.22) at harvest while narrowest LA (1253.00$cm^2$) and LAI (0.67) were recorded in control plots of 80cm depth respectively. Plantains in shallow and deepest trenches mulched with black polythene recorded 0.0 values respectively (Table 29).

### 4.1.12 Ratoon crop protection

#### 4.1.12.1 Black sigatoka leaf spot disease

Table 30 shows that the effect of trench depth (cm) mulch materials and their interaction was not significant on black sigatoka leaf spot disease severity on first ratoon crop of late season plantain at harvest.

### 4.1.13 Reproductive and yield parameters of first ratoon

#### 4.1.13.1 Days to 50% flowering and bunch weight (t $ha^{-1}$)

Table 31 highlights highly significant ($P<0.05$) effects of mulch materials and the

**Table 29: Effect of trench depth (cm) and mulch materials on the number of suckers, leaf area (LA) ($cm^2$), and leaf area index (LAI) of late season plantain first ratoon crop at harvest.**

| **Growth parameters At harvest** | **Sucker** | | | | **Leaf area** | | | | **Leaf area index** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Trench depth (cm)** | | | | | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 3.83 | 4. 83 | 4.50 | 4.39 | 5813.00 | 4743.00 | 5574.00 | 5377.00 | 3.10 | 2.53 | 3.15 | 2.93 |
| Wood shaving | 5.00 | 8.17 | 4.67 | 5.94 | 6377.00 | 7908.00 | 5171.00 | 6485.00 | 3.40 | 4.22 | 2.76 | 3.46 |
| Palm frond | 4.67 | 5.28 | 5.33 | 5.09 | 4081.00 | 5317.00 | 5112.00 | 4837.00 | 2.18 | 2.84 | 2.73 | 2.58 |
| Saw dust | 6.00 | 4.00 | 5.17 | 5.06 | 5727.00 | 4188.00 | 4953.00 | 4956.00 | 3.05 | 2.23 | 2.27 | 2.65 |
| Black polythene | 0.00 | 1.67 | 0.55 | 0.74 | 0.00 | 1541.00 | 0.00 | 514.00 | 0.00 | 0.82 | 0.00 | 0.27 |
| No mulch | 3.60 | 1.67 | 4.00 | 3.09 | 3612.00 | 1253.00 | 4113.00 | 3193.00 | 1.99 | 0.67 | 2.51 | 1.73 |
| Mean | 3.85 | 4.27 | 4.04 | 4.05 | 4268.00 | 4158.00 | 4254.00 | 4227.00 | 2.29 | 2.22 | 2.30 | 2.27 |
| LSD $_{(0.05)}$ Mulch | | | 1.78 | | | 1266.30 | | | | 0.67 | | |
| LSD $_{(0.05)}$ Trench depth | | | ns | | | ns | | | | ns | | |
| LSD $_{(0.05)}$ Mulch x trench depth | | | ns | | | 2193.00 | | | | 1.16 | | |

Ns=not significant, * = not available

**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

**Table 30: Effect of trench depth (cm) and mulch materials on the severity of black sigatoka leaf spot disease on the first ratoon crop of late season plantain at harvest.**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch source** | **60** | **80** | **100** | **Mea** |
| Trash | 1.00 | 0.83 | 1.67 | 1.00 |
| Wood shaving | 0.83 | 0.50 | 0.83 | 0.72 |
| Palm frond | 1.17 | 1.00 | 1.33 | 1.17 |
| Saw dust | 0.83 | 1.17 | 0.83 | 0.83 |
| Black polythene | 0.00 | 1.00 | 0.00 | 0.33 |
| No mulch | 1.50 | 0.67 | 1.17 | 1.11 |
| Mean | 0.83 | 0.86 | 0.89 | 0.86 |
| LSD $_{(0.05)}$ Mulch | ns | | | |
| LSD $_{(0.05)}$ Trench depth | ns | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | ns | | | |

Ns= not significant

**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

interaction of mulch materials and trench depth ($P<0.05$) on the number of days to 50% flowering and bunch weight (t $ha^{-1}$) of first ratoon crop of late season plantain. Trench depth (cm) was not significant on any of the yield parameters. The least number of days to 50% flowering (650.10 days) was recorded in first ratoon crops mulched with wood shavings in medium (80cm depth) trenches, followed by those in 80cm trenches mulched with black polythene (662.00 days). First ratoon crops in shallow trenches mulched with palm frond took the longest time (1227.00 days) to attain 50% flowering, closely followed by first ratoon crops in control plots of same dimension (1177.00 days).

The highest bunch weight at harvest (16.63 t $ha^{-1}$) was recorded in first ratoon crops mulched with wood shavings in 80cm trenches, closely followed by first ratoon crops in shallow trenches mulched with saw dust (14.55 t $ha^{-1}$). The least bunch weight was recorded in first ratoon crops in 80cm control plots (4.77 t $ha^{-1}$) while those in shallow and deepest trenches mulched with black polythene recorded 0.0 t $ha^{-1}$ respectively because there were no suckers (Table 31).

#### 4.1.13.2 Number of hands/bunch, number of fingers/hand and number of fingers/bunch of first ratoon crop of late season plantain

The number of hands/bunch, number of fingers/hand and number of fingers/bunch in late season plantain is shown in Table 32. Trench depth was not significant on any of the yield attributes. However, first ratoon yield attributes responded significantly ($P<0.05$) to mulch materials and the interaction of mulch materials and trench depth in terms of hands/bunch, fingers/hand and fingers/bunch. First ratoon crops in 80cm trenches treated with wood shavings recorded the highest number of hands/bunch (5.44) and number of fingers/bunch (32.23)

**Table 31: Effect of trench depth (cm) and mulch materials on number of days to 50% flowering and bunch weight (tha$^{-1}$) of late season plantain first ratoon crop.**

| | Days to 50% flowering | | | | Bunch weight (t ha$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Trench depth (cm) | | | | | | | |
| **Mulch sources** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| Trash | 855.00 | 869.00 | 811.00 | 845.00 | 13.01 | 11.95 | 14.38 | 13.11 |
| Wood shaving | 774.00 | 650.00 | 1074.00 | 1074.00 | 13.51 | 16.63 | 12.77 | 14.31 |
| Palm frond | 1227. 00 | 1074.00 | 1059.00 | 1120.00 | 12.12 | 12.47 | 13.28 | 12.62 |
| Saw dust | 1102. 00 | 1069.00 | 1102.00 | 1021.00 | 14.55 | 12.30 | 10.25 | 12.36 |
| Black polythene | 0.00 | 662.00 | 0.00 | 221.00 | 0.00 | 6.88 | 0.00 | 2.29 |
| No Mulch | 1177. 00 | 1074.00 | 1147.00 | 906.00 | 8.78 | 4.77 | 11.22 | 8.26 |
| Mean | 816.00 | 786.00 | 871.00 | 824.00 | 10.58 | 10.83 | 10.58 | 10.49 |
| LSD (0.05) Mulch | 203.10 | | | | | 2.10 | | |
| LSD (0.05) Trench Depth | ns | | | | | ns | | |
| LSD (0.05) mulch x trench depth | 351.80 | | | | | 1.79 | | |

Ns=not significant

**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

**Table 32: Effect of trench depth (cm) and mulch materials on the number of hands/bunch, number of fingers/hand and number of fingers/bunch of first ratoon crop of late season plantain.**

| **Growth parameters at harvest** | **Hands/bunch** | | | | **Fingers//hand** | | | | **Fingers/bunch** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trench depth (cm)** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** | **60** | **80** | **100** | **Mean** |
| **Mulch source** | | | | | | | | | | | | |
| Trash | 3.06 | 3.70 | 4.49 | 4.02 | 5.74 | 5.74 | 6.69 | 6.06 | 21.96 | 21.25 | 28.49 | 23.90 |
| Wood shaving | 4.71 | 5.44 | 3.84 | 4.67 | 5.64 | 5.90 | 5.40 | 5.65 | 26.59 | 32.23 | 20.73 | 26.52 |
| Palm frond | 4.39 | 4.16 | 5.02 | 4.41 | 5.34 | 5.88 | 5.18 | 5.46 | 21.65 | 24.46 | 25.99 | 24.04 |
| Saw dust | 5.39 | 4.60 | 3.21 | 4.40 | 5.77 | 5.01 | 4.87 | 5.22 | 31.15 | 23.35 | 15.49 | 23.33 |
| Black polythene | 0.00 | 2.27 | 0.00 | 0.76 | 0.00 | 3.42 | 0.00 | 1.14 | 0.00 | 11.45 | 0.00 | 3.82 |
| No Mulch | 3.63 | 1.09 | 3.81 | 2.84 | 5.10 | 1. 97 | 5.49 | 4.14 | 19.61 | 6.46 | 21.27 | 15.78 |
| Mean | 3.61 | 3.54 | 3.40 | 3.52 | 4.60 | 4.65 | 4.60 | 4.61 | 20.16 | 19.87 | 18.66 | 19.57 |
| LSD $_{(0.05)}$ Mulch | | | 0.71 | | | | 1.12 | | | | 3.13 | |
| LSD $_{(0.05)}$ Trench Depth | | | ns | | | | ns | | | | ns | |
| LSD $_{(0.05)}$ mulch x trench depth | | | 1.23 | | | | 1.98 | | | | 7.66 | |

Ns=not significant

**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

respectively while those crops in 60cm trenches mulched with saw dust recorded the second highest number of hands/bunch (5.39) and fingers/bunch (31.15) respectively. First ratoon crops treated with black polythene in deepest and shallow trenches recorded no yield parameters (0.0) at the termination of the experiment 3 years after planting, while the highest number of fingers/hand was recorded in first ratoon crops in 100cm trenches treated with trash (6.69). Least number of hands/bunch (1.09), fingers/hand (1.97) and fingers/bunch (6.46) was observed in first ratoon crops in control plots 80cm depth.

**4.1.14 Total yield**

The total yield (t $ha^{-1}$) of late season plant and first ratoon crop of plantain (Table 33) indicated highly significant ($P<0.05$) differences among treatment means due to application of different mulches and the interaction (P,0.05) of trench depth and mulch materials. Trench depth (cm) had no significant effect on total yield. The highest total yield (t $ha^{-1}$) was obtained in plots treated with wood shavings in 80cm trenches (38.45 t $ha^{-1}$), followed by shallow trenches mulched with saw dust (31.94 t $ha^{-1}$) and wood shavings (30.14 t $ha^{-1}$). Deepest trenches mulched with black polythene recorded the lowest total crop yield (13.92 t $ha^{-1}$) closely followed by shallow trenches mulched with same (14.11 t $ha^{-1}$)

**4.1.15 Plantain mat**

**4.1.15.1 Height of plantain mat (cm)**

The height of plantain mat at harvest of first ratoon crop (Table 34) showed highly significant ($P<0.05$) effect of trench depth (cm), but mulch materials and interaction of trench depth and mulch materials were not significant.The highest plantain mat was recorded in 100cm trenches mulched with black polythene (45.33cm) followed by 100cm control plots (44.08cm). The 60cm trenches mulched with palm frond recorded the least height of plantain

**Table 33: Effect of trench depth (cm) and mulch materials on the total yield ($tha^{-1}$) of plant and first ratoon crop of late season plantain.**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch sources** | **60** | **80** | **100** | **Mean** |
| Trash | 27.92 | 26.50 | 28.67 | 27.69 |
| Wood shaving | 30.14 | 38.45 | 27.48 | 32.02 |
| Palm frond | 26.09 | 27.24 | 27.26 | 26.86 |
| Saw dust | 31.94 | 26.94 | 24.38 | 27.75 |
| Black polythene | 14.11 | 21.08 | 13.92 | 16.37 |
| No Mulch | 22.04 | 17.31 | 24.24 | 21.20 |
| Mean | 25.37 | 26.25 | 24.32 | 25.32 |
| $LSD_{(0.05)}$ Mulch | 2.45 | | | |
| $LSD_{(0.05)}$ Trench depth | ns | | | |
| $LSD_{(0.05)}$ mulch x trench depth | 4.24 | | | |

**Ns=Not significant**
**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

**Table 34: Effect of trench depth and mulch materials on the height (cm) of late season plantain mat at harvest of first ratoon crop.**

| | **Trench depth (cm)** | | | |
|---|---|---|---|---|
| **Mulch Sources** | **60** | **80** | **100** | **Mean** |
| Trash | 30.83 | 33.39 | 41.67 | 37.97 |
| Wood shaving | 30.50 | 32.26 | 41.82 | 34.86 |
| Palm frond | 29.56 | 37.97 | 40.48 | 36.00 |
| Saw dust | 29.88 | 33.39 | 41.67 | 34.98 |
| Black polythene | 32.17 | 38.40 | 45.33 | 38.63 |
| No mulch | 31.18 | 39.58 | 44.08 | 38.28 |
| Mean | 30.69 | 37.17 | 42.51 | 36.79 |
| LSD $_{(0.05)}$ Mulch | ns | | | |
| LSD $_{(0.05)}$Trench depth | 2.41 | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | ns | | | |

**Ns=Not significant**
**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

mat (29.56cm) followed by 60cm trenches mulched with saw dust (29.88cm) at harvest of first ratoon crop of late season plantain.

#### 4.1.15.2 Rate of mat growth (cm/month).

Table 35 showed significant ($P<0.05$) effect of trench depth (cm) and mulch materials ($P<0.05$) on the rate of late season plantain mat growth. Highest rate of plantain mat growth was recorded in 100cm trenches mulched with black polythene (1.89 cm/month), closely followed by control plots of same dimension (1.83 cm/month) while 60cm trenches mulched with palm frond recorded the least rate (1.23 cm/month). Generally, the deepest trenches (100 cm depth) recorded higher rates of plantain mat growth than shallower trenches (80 cm and 60cm).The interaction of trench depth and mulch materials was not significant on rate of plantain mat growth.

### 4.1.16 Post experimental soil physico-chemical characterization

The post experimental soil physico-chemical analysis showed increase in soil pH, Nitrogen (N), Phosphorus (P), Calcium (Ca), Organic matter (OM) and Organic Carbon (OC) at different trench dephts and mulch materials compared to the pre-experimental physico-chemical characteristics (Table 36). Highest soil pH in $H_2O$ (6.21) and KCl (5.88) was recorded in 80cm trenches mulched with palm frond followed by 80cm trenches mulched with black polythene which had soils with pH of 6.19 in $H_2O$ and 80cm trenches mulched with wood shavings which had soils with pH of 5.87 in KCL The highest value for Nitrogen (0.28%) was recorded in soils treated with black polythene in 100cm trenches followed by soils in the control plots of 100cm (0.17%). The highest value for available Phosphorus was recorded in 60cm trenches mulched with trash (12.36 mg $kg^{-1}$) followed by 100cm trenches mulched with saw dust (12.20 mg $kg^{-1}$). Trenches of 100cm dimension mulched with black polythene recorded the lowest value for Phosphorus (1.66 mg $kg^{-1}$). The highest

**Table 35: Effect of trench depth (cm) and mulch materials on the rate of plantain mat growth (cm/month).**

| | Trench depth (cm) | | | |
|---|---|---|---|---|
| **Mulch Sources** | **60** | **80** | **100** | **Mean** |
| **Trash** | 1.28 | 1.73 | 1.74 | 1.58 |
| **Wood shaving** | 1.27 | 1.34 | 1.34 | 1.45 |
| **Palm frond** | 1.23 | 1.58 | 1.67 | 1.49 |
| **Saw dust** | 1.24 | 1.39 | 1.74 | 1.46 |
| **Black polythene** | 1.43 | 1.67 | 1.89 | 1.66 |
| **No mulch** | 1.29 | 1.65 | 1.83 | 1.59 |
| **Mean** | 1.29 | 1.56 | 1.77 | 1.54 |
| LSD $_{(0.05)}$ Mulch | 0.15 | | | |
| LSD $_{(0.05)}$ Trench depth | 0.10 | | | |
| LSD $_{(0.05)}$ Mulch x trench depth | ns | | | |

Ns=not significant

**60=60x60x60cm dimension, 80=60x60x80cm dimension, 100=60x60x100cm dimension**

**Table 36: Post experimental soil physico-chemical characteristics as affected by trench depth (cm) and mulch materials (trash, palm frond and wood shaving)**

| Soil property<br>Treatment | pH<br>$H_2O$ | pH<br>KCL | Exch<br>$H^+$ | Exch<br>$Al^{3+}$<br>(Cmol kg$^{-1}$) | Exch<br>Acidity<br>(Cmol kg$^{-1}$) | Exch<br>$Ca^{2+}$<br>(Cmol kg$^{-1}$) | Exch<br>$Mg^{2+}$<br>(Cmol kg$^{-1}$) | Exch<br>Na<br>(Cmol kg$^{-1}$) | Exch<br>$K^+$<br>(Cmol kg$^{-1}$) | ECEC<br>(Cmol kg$^{-1}$) | Base<br>Satu | Total<br>N(%) | Avail<br>P mgl kg$^{-1}$) | organic<br>Matter<br>% | Organic<br>Carbon<br>(%) | %<br>Sand | %<br>Silt | %<br>clay | Textu<br>CLS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trench depth (cm)** | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | **Trash** | | | | | | | | | | |
| **60** | 5.54 | 5.66 | 0.70 | 0.80 | 1.50 | 1.60 | 1.20 | 0.11 | 0.16 | 4.57 | 67.10 | 0.03 | 12.36 | 0.65 | 0.37 | 90.80 | 4.0 | 5.20 | SS |
| **80** | 6.12 | 5.66 | 0.20 | 0.50 | 0.70 | 1.80 | 0.80 | 0.26 | 0.23 | 2.75 | 76.00 | 0.01 | 8.90 | 0.24 | 0.13 | 80.80 | 8.00 | 11.20 | SL |
| **100** | 5.99 | 5.70 | 0.70 | 0.40 | 1.10 | 1.80 | 1.20 | 1.14 | 0.20 | 4.44 | 75.20 | 0.08 | 11.71 | 1.71 | 0.99 | 86.80 | 4.00 | 2.20 | SS |
| | | | | | | | | | **Palm frond** | | | | | | | | | | |
| **60** | 6.04 | 5.82 | 0.40 | 0.80 | 1.20 | 2.00 | 1.00 | 0.11 | 0.16 | 4.67 | 74.30 | 0.06 | 12.15 | 1.31 | 0.75 | 82.80 | 4.00 | 13.20 | SL |
| **80** | 6.21 | 5.88 | 0.40 | 0.20 | 0.60 | 1.60 | 0.80 | 0.21 | 0.11 | 3.32 | 81.9 | 0.04 | 11.52 | 0.82 | 0.47 | 84.80 | 6.00 | 9.20 | SS |
| **100** | 5.81 | 5.76 | 0.40 | 1.00 | 1.40 | 1.20 | 1.20 | 0.09 | 0.15 | 4.04 | 65.30 | 0.06 | 11.06 | 1.20 | 0.69 | 86.80 | 6.00 | 11.20 | LS |
| | | | | | | | | | **Wood shaving** | | | | | | | | | | |
| **60** | 5.80 | 5.71 | 0.10 | 0.50 | 0.60 | 1.80 | 1.00 | 0.11 | 0.16 | 3.71 | 67.11 | 0.03 | 9.30 | 0.14 | 0.08 | 86.80 | 6.00 | 7.20 | SS |
| **80** | 6.05 | 5.87 | 0.40 | 0.60 | 1.00 | 2.00 | 1.60 | 0.13 | 0.15 | 4.86 | 79.80 | 0.04 | 9.16 | 0.85 | 0.49 | 86.80 | 6.80 | 11.20 | SL |
| | 5.88 | 5.62 | 0.40 | 0.00 | 1.40 | 2.00 | 1.60 | 0.07 | 0.24 | 5.35 | 73.40 | 0.07 | 8.85 | 1.54 | 0.89 | 86.80 | 4.00 | 7.20 | SS |

**Table 36 continued: Post experimental soil physic-chemical characteristics as affected by trench depth and mulch materials (cm) (saw dust, black polythene and no mulch)**

| Soil property Treatment | pH $H_2O$ | pH KCL | Exch $H^+$ | Exch $Al^{3+}$ ($Cmol\ kg^{-1}$) | Exch acidity | Exch $Ca^{2+}$ ($Cmol\ kg^{-1}$) | Exch $Mg^{2+}$ ($Cmol\ kg^{-1}$) | Exch Na ($Cmol\ kg^{-1}$) | Exch $K^+$ ($Cmol\ kg^{-1}$) | ECEC | Base Satu | Total N(%) | Avail P ($mg\ kg^{-1}$) | organic Matter % | Organic Carbon(%) | % Sand | % Suit | % clay | Text CLS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Saw dust** | | | | | | | | | | | | | | | | | | | |
| **60x60x60** | 5.99 | 5.71 | 0.40 | 0.20 | 1.60 | 1.40 | 0.80 | 0.13 | 0.27 | 3.20 | 81.20 | 0.01 | 10.00 | 0.12 | 0.21 | 79.80 | 6.00 | 17.20 | SL |
| **80** | 5.98 | 5.83 | 0.50 | 0.70 | 1.00 | 1.20 | 1.00 | 0.09 | 0.14 | 3.43 | 70.80 | 0.04 | 10.96 | 0.49 | 0.85 | 86.80 | 6.00 | 11.20 | SL |
| **100** | 5.82 | 5.72 | 0.10 | 0.80 | 1.00 | 2.00 | 1.60 | 1.18 | 0.18 | 5.75 | 82.60 | 0.12 | 12.20 | 1.39 | 2.40 | 94.80 | 0.40 | 4.80 | SS |
| **Black polythene** | | | | | | | | | | | | | | | | | | | |
| **60** | 6.07 | 4.98 | 0.30 | 0.60 | 0.90 | 2.40 | 1.60 | 0.08 | 0.11 | 5.09 | 82.30 | 0.13 | 2.50 | 1.51 | 2.61 | 82.80 | 4.00 | 13.20 | LS |
| **80** | 6.19 | 5.04 | 0.50 | 0.65 | 1.15 | 2.20 | 1.20 | 0.09 | 0.15 | 4.79 | 75.90 | 0.10 | 1.96 | 1.22 | 2.09 | 84.80 | 2.00 | 13.20 | LS |
| **100** | 5.77 | 5.04 | 0.30 | 0.90 | 1.30 | 3.20 | 2.40 | 0.11 | 0.09 | 7.10 | 81.60 | 0.28 | 1.66 | 3.25 | 5.61 | 84.80 | 2.00 | 13.20 | LS |
| **No mulch** | | | | | | | | | | | | | | | | | | | |
| **60** | 6.02 | 5.46 | 0.60 | 0.10 | 0.70 | 2.40 | 1.20 | 0.13 | 0.16 | 4.55 | 85.40 | 0.10 | 10.12 | 1.24 | 2.13 | 86.80 | 4.00 | 9.20 | SS |
| **80** | 6.16 | 5.58 | 0.50 | 0.90 | 1.40 | 2.40 | 2.20 | 0.18 | 0.13 | 6.11 | 77.00 | 0.11 | 8.45 | 1.22 | 3.23 | 84.80 | 4.00 | 11.20 | LS |
| **100** | 6.14 | 5.13 | 0.40 | 0.70 | 1.10 | 2.40 | 1.20 | 0.13 | 0.20 | 5.03 | 78.10 | 0.17 | 7.06 | 2.07 | 3.57 | 95.00 | 0.40 | 4.60 | SS |

value for calcium was recorded in soils treated with black polythene in 100cm trenches (3.20 cmol $kg^{-1}$) while 80cm trenches mulched with saw dust and palm frond mulched trenches of 100cm recorded the least value (1.20 cmol $kg^{-1}$). Magnesium was highest in 100cm trenches mulched with black polythene (2.40 cmol $kg^{-1}$) while the lowest value (0.8 cmol $kg^{-1}$) was recorded in 60cm trenches treated with saw dust and 80cm trenches mulched with trash and palm frond respectively. The highest value for organic matter was recorded in 100cm trenches mulched with black polythene (5.61%) while 60cm trenches mulched with saw dust had the least value of organic matter (0.12%). The highest effective cation exchange capacity (ECEC) was obtained in soils in 100cm trenches mulched with black polythene (7.10cmol$kg^{-1}$) while 80cm trenches mulched with trash recorded the lowest ECEC (2.75).

### 4.1.17 Input output cost analysis for plant and first ratoon crops

The input output cost analysis for late season plantain plant and first ratoon crop highlighted in Table 37 showed that late season plantain production with poultry manure rates of 10$tha^{-1}$ and different mulches and trench depths gave high economic returns. The highest benefit-cost ratio (5.06) was obtained in plantains in medium trenches mulched with wood shavings closely followed by those mulched with same in shallow trenches (4.77) and plantains treated with trash in shallow (4.66), medium (4.18) and deepest( 4.06) trenches respectively. Plantains treated with palm frond in 60, 80 and 100cm trenches also gave high benefits-cost ratio (3.51, 3.61 and 3.54) respectively as well as those in shallow trenches mulched with saw dust (3.60). The least benefit-cost ratio (1.78, 1.56) was obtained when late season plantains were mulched with black polythene in shallow and deepest trenches respectively.

**Table 37: Input output cost analysis for late season plantain plant and first ratoon enterprise (tha$^{-1}$)**

| | Cultural practice | | | | | |
|---|---|---|---|---|---|---|
| | | Poultry + | Manure + | Trench depth+ | mulch | |
| **Input** | **10tha$^{-1}$ PM + 60x60x60cm/2kg trash** | **10tha$^{-1}$ PM + 60x60x80cm/2kg trash** | **10tha$^{-1}$ PM + 60x60x100cm/2kg trash** | **10tha$^{-1}$ PM + 60x60x60cm/2kg wood shaving** | **10tha$^{-1}$ PM + 60x60x80cm/2kg wood shaving** | **10tha$^{-1}$ PM + 60x60x1000cm /2kg wood shaving** |
| Land clearing (tha$^{-1}$) @ ₦1800.00/man day for 34.72mandays | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 |
| Digging holes | 123,481.48 | 174,932.09 | 226,382.72 | 123,481.48 | 174,932.09 | 226,382.72 |
| Plantainsuckers@ ₦70each | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 |
| Planting labour | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 |
| Wood shaving (loading and off-loading | 0.00 | 0.00 | 0.00 | 6,668.00 | 6,668.00 | 6,668.00 |
| Wood shaving (transportation) | 0.00 | 0.00 | 0.00 | 20,580.25 | 20,580.25 | 20,580.25 |
| Trash (transport to drying site) | 5,934.00 | 5,934.00 | 5,934.00 | 0.00 | 0.00 | 0.00 |
| Cost of poultry manure | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 |
| Transportation of poultry manure | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 |
| Weeding( man days/ha/) @ ₦1,800.00per man day | 338,936.00 | 338,936.00 | 338,936.00 | 338,936.00 | 338,936.00 | 338,936.00 |
| Harvesting labour (plant & ratoon) @ N1,800.00/manday for 34.30 mandays | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 |
| Desuckering @ N1,800.00/manday for 28.58 mandays/ha | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 |
| **Total cost** | **877,237.98** | **931,655.59** | **983,106.22** | **895,518.51** | **952,969.12** | **1,004,419.75** |
| **Output** | | | | | | |
| Sale of suckers | 1,100,200.20 | 1,050,210.00 | 933,520.00 | 1,108,555.00 | 1,866,877.30 | 982,529.80 |
| Plantain bunch weight plant crop (tha$^{-1}$) | 14.91 | 14.55 | 13.95 | 15.29 | 20.88 | 14.70 |
| Plantain bunch weight ratoon (tha$^{-1}$) | 13.01 | 11.95 | 14.38 | 13.51 | 16.63 | 12.77 |
| Sale of bunch plant crop(tha$^{-1}$) | 1,584,900.25 | 1,559,811.90 | 1,500,600.06 | 1,667,000.00 | 2,167,100.00 | 1,525,438.36 |
| Sale of bunch ratoon crop(tha$^{-1}$) | 1,401,396.89 | 1,284,840.25 | 1,560,278.60 | 1,501,633.60 | 1,725,379.09 | 1,324,900.24 |
| **Total revenue** | **4,086, 497.33** | **3,894,862.15** | **3,994,398.66** | **4,277,188.60** | **5,779,356.39** | **3,892,868.40** |
| **Total profit** | 3,209,259.35 | 2,963,206.56 | 3,011,292.44 | 3,381,670.09 | 4,826,387.27 | 2,828,448.65 |
| BCR | 4.66 | 4.18 | 4.06 | 4.77 | 5.06 | 2.81 |

PM = Poultry manure, BCE= benefit cost ratio, sucker price = ₦70/sucker

**Source of cost:** Farm gate price of Federal University of Technology Owerri. Plantain bunch price for trash 60x60x60cm = N950.75k and N809.67k/bunch (plant and ratoon crop), 60x60x80cm = N904.70k and N770.7k/bunch (plant and ratoon crop), N900.18k and N935.98k/bunch (plant and ratoon, 60x60x100cm). for wood shavings 60x60x60cm = N1050.08k and N900.80k (plant and ratoon), 60x60x80cm = N1,300.00 and N1,035/bunch (plant and ratoon), 60x60x100 = N915.08k and N794.78k (plant and ratoon). Mandays= total number of mandays for project cycle

**Table 37 continued:Input output cost analysis for late season plantain plant and first ratoon enterprise (tha$^{-1}$)**

| | Cultural practice | | | | | |
|---|---|---|---|---|---|---|
| | Poultry Manure + Trench dept h+ mulch | | | | | |
| **Input** | **10tha$^{-1}$PM + 60x60x60cm/2kg palm frond** | **10tha$^{-1}$PM + 60x60x80cm/2kg palm frond** | **10tha$^{-1}$PM + 60x60x100cm/2kg palm frond** | **10tha$^{-1}$PM + 60x60x60cm/2kg saw dust** | **10tha$^{-1}$PM + 60x60x80cm/2kg saw dust** | **10tha$^{-1}$PM + 60x60x1000cm/2kg saw dust** |
| Land clearing (tha$^{-1}$) @ ₦1800/00/man day for 34.7mandays | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 |
| Digging holes | 123,481.48 | 174,932.09 | 226,382.72 | 123,481.48 | 174,932.09 | 226,382.72 |
| Plantainsuckers@ ₦70 each | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 |
| Planting labour | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 |
| Palm frond (loading & offloading) | 5,344.00 | 5,344.00 | 5,344.00 | 0.00 | 0.00 | 0.00 |
| Palm frond (transportation) | 14,973.05 | 14,973.05 | 14,973.05 | 0.00 | 0.00 | 0.00 |
| Cost of Poultry manure | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 | 75,015.00 |
| Transportationof poultry manure | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 |
| Saw dust (loading & offloading) | 0.00 | 0.00 | 0.00 | 9,335.70 | 9,335.00 | 9,335.00 |
| Saw dust (transportation) | 0.00 | 0.00 | 0.00 | 29,955.09 | 24,955.09 | 24,955.00 |
| Weeding (mandays/ha) @ N1,800.00/manday | 485,136.00 | 457,936.00 | 579,936.00 | 430,736.00 | 457,936.00 | 457,936.00 |
| Harvest labour (plant & ratoon)@N1,800.00/mandays for 34.30mandays/ha | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 |
| Desuckering for 28.58 mandays @ N1,800.00/manday | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 |
| **Total cost** | **1,040,797.83** | **1,065,037.92** | **1,136,488.55** | **1,274,956.36** | **1,762,019.16** | **1,138,461.09** |
| **Output** | | | | | | |
| Sale of suckers | 1,011,072.30 | 1,142,395.10 | 1,205,407.76 | 1,283,590.00 | 895,175.00 | 1,140,061.30 |
| Plantain bunch weight plant crop (tha$^{-1}$) | 13.97 | 14.77 | 13.98 | 16.72 | 14.64 | 13.93 |
| Plantain bunch weight ratoon (tha$^{-1}$) | 12.12 | 12.47 | 13.28 | 14.55 | 12.30 | 10.25 |
| Sale of/bunch plant crop(tha$^{-1}$) | 1,387,660.81 | 1,411,015.48 | 1,450,383.13 | 1,800,360.00 | 1,518,914.60 | 1,445,251.40 |
| Sale of bunch ratoon crop | 1,257,367.68 | 1,293,687.06 | 1,377,813.25k | 1,508,149.40 | 1,276,392.50 | 1,063,447.73 |
| **Total revenue** | **3,656,730.97** | **3847,097.64** | **4,033,604.14** | **4,592,099.40** | **3,690,482.10** | **3,648,760.43** |
| Total profit | 2,615,132.96 | 2,782,059.72 | 2,897,115.59 | 3,317,143.04 | 2,612,270.94 | 2,519,099.34 |
| BCR | 3.52 | 3.61 | 3.54 | 3.60 | 2.09 | 3.20 |

PM = Poultry manure, BCE= benefit cost ratio: **Source of cost:** Farm gate price of Federal University of Technology Owerri. Plantain bunch price for palm frond 60x60x60cm = N832.43k and N754.27k/bunch and N870.05k/bunch (60x60x60cm plant and ratoon). Saw dust = N1080.00 and N904.71k/bunch (60x60x60cm, plant and ratoon), N911.17k and N765.68k/bunch (plant and ratoon, 60x60x80cm), N866.98k and N637.94k/bunch (plant and ratoon, 60x60x100cm). Mandays= total number of man days for project cycle

**Table 37 continued: Input output cost analysis for late season plantain plant and first ratoon enterprise (tha$^{-1}$)**

| | Cultural practice | | | | | |
|---|---|---|---|---|---|---|
| | Poultry Manure + Trench depth + mulch | | | | | |
| **Input** | **10tha$^{-1}$PM + 60x60x60cm /black polythene** | **10tha$^{-1}$PM + 60x60x80cm/ black polythene** | **10tha$^{-1}$PM + 60x60x100cm black polythene** | **10tha$^{-1}$PM + 60x60x60cm/no mulch** | **10tha$^{-1}$PM + 60x60x80cm/ no mulch** | **10tha$^{-1}$PM +60x60x1000cm/no mulch** |
| Land clearing (tha$^{-1}$) @ ₦1,800/man day for 34.7 mandays | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 | 62,500.00 |
| Digging holes | 123,481.48 | 174,932.09 | 226,382.72 | 123,481.48 | 174,932.09 | 226,382.72 |
| Plantainsuckers@ ₦70 each | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 | 116,690.00 |
| Planting labour | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 | 41,160.49 |
| Black polythene @ ₦10/sheet | 16,670.00 | 16,670.00 | 16,670.00 | 0.00 | 0.00 | 0.00 |
| Transportation of black polythene | 500.00 | 500.00 | 500.00 | 0.00 | 0.00 | 0.00 |
| Cost of poultry manure | 70,015.00 | 70,015.00 | 70,015.00 | 70,015.00 | 70,015.00 | 70,015.00 |
| Transportation of poultry manure | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 3,296.70 | 40,584.42 |
| Weeding (man days/ha) @ ₦1,800.00/manday | 272,436.17($1^{3}/_{4}$) | 457,936.00($3^{1}/_{4}$) | 272,436.17($1^{3}/_{4}$) | 457,936.00($3\ ^{1}/_{4}$) | 485,137.68($3^{1}/_{2}$) | 485,137.68($3^{1}/_{2}$) |
| Desuckering for 28.58 mandays @ ₦1,800.00/mandays/ha | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 | 51,450.59 |
| Harvesting labour (plant & ratoon) @ ₦1,,800.00/manday for 34.30 mandays/ha | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 | 61,740.00 |
| **Total cost** | **819,940.18** | **1,056,890.87** | **922,842.15** | **988,270.31** | **996,977.00** | **1,108,373.18** |
| **Output** | | | | | | |
| Sale of Plantain sucker | 0.00 | 950,070.00 | 0.00 | 721,144.20 | 485,597.30 | 884,501.20 |
| Sale of bunch (tha$^{-1}$)plant crop | 1,462,835.73 | 1,525,098.79 | 1,444,156.82 | 1,373,592.04 | 1,403,750.99 | 1,376,775.74 |
| Sale of bunch (tha$^{-1}$)ratoon crop | 0.00 | 933,520.00 | 0.00 | 910,933.76 | 926,018.10 | 1,200,240.00 |
| Plantain bunch weight(tha$^{-1}$)plant crop | 14.00 | 14.70 | 13.92 | 13.24 | 13.53 | 13.27 |
| Plantain bunch weight(tha$^{-1}$)1$^{st}$ ratoon | 0.00 | 6.88 | 0.00 | 8.78 | 4.70 | 11.22 |
| Total revenue | **1,462,835.78** | **3,408,688.00** | **1,444,1456.82** | **3,005,670.00** | **2,815,366.09** | **3,461,456.94** |
| Total profit | 642,895.35 | 2,351,797.13 | 521,314.67 | 2,017,399.69 | 1,818,389.09 | 235,308.76 |
| BCR | 1.78 | 3.23 | 1.56 | 3.04 | 2.82 | 3.12 |

PM = Poultry manure, BCE= benefit cost ratio

**Source of cost:** Farm gate price of Federal University of Technology Owerri. Plantain bunch price for black polythene 60x60x60cm = N877.53k (plant crop), 60x60x80cm = N914.88k and N560.00/bunch (plant and ratoon crop), 60x60x100cm = N866.32k (plant crop). No mulch 60x60x60 = N823.99k and N546.45k/bunch (plant and ratoon), 60x60x80cm = N842.08k and N550.50k/bunch (plant and ratoon). 60x60x100cm = N825.90k and N720.00/bunch (plant and ratoon). Man days = total number of man days for project cycle.

### 4.1.18 Correlation coefficients

Table 38 highlights the correlation coefficients of plant growth parameters at six MAP, weed dry weight at six MAP and yield attributes of late season plantain plant crop at harvest. Plantain pseudostem height correlated positively and significantly with psedostem girth, leaf area, number of suckers, and negatively with and significantly with days to 50% flowering. Plantain pseudostem girth correlated positively and significantly with number of leaves, leaf area, number of suckers at six MAP and number of fingers/bunch at harvest while correlating negatively and significantly with days to 50% flowering. At six MAP, plantain leaf area correlated positively and significantly with number of suckers, and negatively and significantly with days to 50% flowering.The number of suckers produced in late season plantain correlated negatively and significantly with days to 50% flowering, and positively and significantly with bunch weight and number of fingers at harvest.The number of days to 50% flowering correlated negatively and significantly with bunch weight and number of fingers /bunch at harvest while plantain bunch weight at harvest correlated positively and significantly with number of fingers at harvest of plant crop (Table 38).

The correlation coefficients of plant growth parameters, protection and yield attributes and at harvest are shown in Table 39. Plantain pseudostem height correlated posively and significantly with bunch weight at harvest and number of fingers/ bunch, but negatively and significantly with weed dry weight and days to 50% flowering. Plantain pseudostem girth at harvest correlated positively and significantly with bunch weight and number of fingers/bunch at harvest, and negatively and significantly with days to 50% flowering. While number of leaves at harvest correlated negatively and significantly with black Sigatoka leaf spot disease severity, weed dry weight and number of days to 50% flowering, there was positive and significant correlation between number of leaves at harvest, bunch weight and number of fingers/bunch at harvest. At harvest, plantain leaf area correlated posively and

**Table 38: Correlation coefficient of late season plantain growth and yield attributes as affected by trench depth (cm) and mulch materials at 6 months after planting.**

| | *Pht* | *Gth* | *Nlvs* | *LA* | *Nsuks* | *Wdwt* | *D50fl* | *Bchwt* | *Nfngs* |
|---|---|---|---|---|---|---|---|---|---|
| Pht | | .872 ** | .045** | .883** | .614** | .161 | -.435 | .332 | .323 |
| Gth | | | .595** | .796** | .679** | .291 | -.544* | .435 | .510* |
| Nlvs | | | | .296 | .254 | .116 | -.176 | .050 | .213 |
| LA | | | | | .513* | .087 | -.539* | .412 | .309 |
| Nsuks | | | | | | .237 | -.673** | .653** | .636** |
| Wdwt | | | | | | | -.15 | -.179 | 0.03 |
| D50fl | | | | | | | | -.767** | -.676** |
| Bchwt | | | | | | | | | .720** |
| Nfngs | | | | | | | | | |

*Correlation is significant at the 0.05 level; **Correlation is significant at the0.01 level

Pht - pseudostem height (cm) at 6MAP
Gth - pseudostem girth (cm) at 6MAP
Nlvs - number of leaves at 6MAP
Bchwt - bunch weight at harvest
LA -leaf area at 6MAP
Wdwt - weed dweight at 6MAP
Nsuks - number of suckers at 6MAP
D50fl -days to 50% flowering
Nfngs - number of fingers/bunch at harvest

Significantly with number of suckers, bunch weight and number of fingers/bunch but there was negative correlation with weed dry weight and days to 50% flowering. There was a negative and significant correlation between number of suckers at harvest and days to 50% flowering, but sucker number was positively and significantly correlated with plantain bucch weight and number of fingers/bunch at harvest. Weed dry weight at harvest was positively and significantly correlated with days to 50% flowering while being negatively but significantly correlated with bunch weight and number of fingers/bunch at harvest. Days to 50% flowering correlated negatively and significantly with plantain bunch weight and number of fingers/bunch at harvest while there was a positive and significant correlation between number of fingers/bunch and bunch yield at harvest of plant crop.

**Table 39: Correlation coefficient of late season plantain growth, yield parameters and protection as affected by trench depth and mulch materials at harvest of plant crop.**

| | *Pht* | *Gth* | *Nlvs* | *LA* | *Nsuks* | *Bsig* | *Wdwt* | *D50fl* | *Bchwt* | *Nfngs* |
|---|---|---|---|---|---|---|---|---|---|---|
| Pht | | .885 ** | .713** | .791** | .737** | -.331 | -.820** | -.623** | .561* | .713** |
| Gth | | | .664** | .765** | .629** | -.138 | -.688** | -.485* | .484* | .662** |
| Nlvs | | | | .564* | .702** | -.152 | -.709** | -.646** | .567* | .647** |
| LA | | | | | .783** | -.286 | -.604** | -.705** | .774** | .662** |
| Nsuks | | | | | | -.003 | -.668** | -.647** | .665** | .733** |
| Bsig | | | | | | | .245 | .428 | -.415 | -.153 |
| Wdwt | | | | | | | | .571* | -.563* | -.505* |
| D50fl | | | | | | | | | -.767** | -.676** |
| Bchwt | | | | | | | | | | .720** |

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level

Pht - pseudostem height at harvest
Gth - pseudostem girth at harvest
Nlvs - number of leaves at harvest
LA -leaf area at harvest
Nsuks - number of suckers at harvest
Nfngs - number of fingers/bunch at harvest.
Wdwt - weed dry weght at harvest
D50fll -days to 50% flowering
Bsig - black sigatoka severity at harvest

## 4.2 DISCUSSION

### 4.2.1 Pre-planting soil physico-chemical characterization.

The result on soil physico-chemical characteristics indicated that the soil is acidic at all trench depths (60, 80 and 100cm), with low organic matter content, organic carbon, total nitrogen and available phosphorus.Soil acidity increased with depth. The soil is also infertile and the base saturation suggests the dominance of 1:1 clays. This result agrees with earlier work done by Ohiri (1992) and Onweremadu *et al.* (2007). While Ohiri (1992) reported that generally all soils in Imo, Abia and Akwa Ibom States are of low fertility, Onweremadu *et al.* (2007) reported specifically that soils in the study area (University farms) were characterized by low pH, low organic matter content, low exchangeable cations and cation exchange capacity, low total Nitrogen content and low available Phosphorus and calcium. The low pH represents a limiting factor for increased productivity of agricultural tree crops and could be remedied by application of appropriate rates of soil amendments like organic manure, organic mulch, lime, etc (Onweremadu *et al.,* 2007). Increase in soil pH with depth was also reported by Onweremadu *et al.*(2007) who noted that increase in pH with depth is indicative of illiniation of basic cations translocated after intensive leaching from the surface horizons. However, the values obtained for soil fertility parameters (cation cxchange capacity, organic carbon, base saturation, total nitrogen and available phosphorus) have been reported to be below recommended levels for optimal productivity in tropical soils in Nigeria (FDALR, 1985; Enwezor *et al.,* 1990). Decreasing values obtained for calcium, magnesium, and sodium with increasing trench depth has also been confirmed by Onweremadu *et al.* (2007) who noted that values of these nutrients were higher in surface and middle horizons of all soils in the study area at 0-10cm and 10-20cm depths respectively.

### 4.2.2 Soil macro biological life

The relatively high populations of big black ants and termites recorded in trenches mulched with trash and palm fronds at one and two months after planting (MAP) may be attributed to the fact that termites found in tropical areas have been reported to preferably feed on timber, leaf, grass, or other crop residues (Wikipedia, 2012). Hence trash which consisted mainly of leaves of vegetation slashed from clearing the experimental plots, as well as palm founds were preferred and rapidly degraded by termites (Becker, 2003; Wikipedia, 2012) within few weeks after planting. This report is corroborated by Obiefuna (1985) that grass mulch used in late season plantains was rapidly degraded by termites, hence offering poor protection to plantain further into the dry season. Mommer *et al.* (2013) reported that as detrivores, termites clear away leaf and woody litter. This rapid degradation of vegetation used as mulch may have resulted in the gradual reduction in termite and big black ant populations at three MAP. The absence of termites and big black ants in plots mulched with saw dust and wood shavings may be attributed to the chemical and lignin content of the woody cells. Further to this, Becker (2003) explained that a number of tree species have a natural chemical resistance of their heart wood to termites. Defence is typically and especially achieved by secreting anti-feedant chemicals (such as oils, resins and lignin) into woody cells. This reduces the ability of termites to efficiently digest the cellulose (Wikipedia, 2012). Termites have also been reported to migrate to the surface in search of food in the dry season, hence the higher populations of termites in 60x60x60cm plots mulched with trash and palm fronds at one and two MAP (Feb. 2011).

The significant effect of mulch materials on millipede population at one to three MAP may be attributed to the presence and type of suitable mulch materials. Although the millipede population was relatively low, and the late season characterized by drier weather conditions, the mulch sources still supported millipede because of the cooling effect sought by these organisms. Millipedes have been reported to thrive in dark, cool, moist areas of high relative humidity and are found in abundance in heavily mulched gardens (USAF, 1991) and require moist habitat and high relative humidity. The palm frond may have provided suitable food at one to three MAP (January – March 2011). The tunnels or galleries created by termites in those plots also may have resulted in lower temperature within the trenches especially the deepest trenches mulched with palm frond at one to three MAP, hence higher millipede population. The gradual reductions in millipede populations from one to three MAP may have been due to increasing soil temperatures from January to March 2011 which corresponded with the peak of the dry season. Although the moisture content increased progressively in all trench depths and mulch sources from one to three MAP at 0-15cm and 15-30 cm depths from the base of the trenches respectively. The increasing high temperature may have made the trenches unconducive for millipede survival. This is true because millipedes are forced by drought conditions to migrate (USAF 1991) to cooler or wetter environments.

The non significant response of cricket, snail and earthworm populations at one to two MAP, and crickets at three MAP may be attributed to high temperatures in January to March ( Table 11) with little rainfall to provide sufficient moisture (Table 4). This is in line with Chikezie *et al.* (2008) who reported that earthworms are highest in abundance towards the end of the rainy season. Soil moisture, temperature, humidity and rainfall play an important role in the distribution of earthworms (Chikezie *et al.*, 2008; Kale & Kermegam, 2010). Furthermore the abundance and species diversity of earthworms are dependent on climatic conditions, especially occurrence of dry or cold periods and regional variations in vegetation, soil texture and nutrient content (Kale & Kermegam, 2010). According to Kale & Kermegam (2010), the highest rainfall (October/November) correlated with highest earthworm population in October to November and highest soil moisture content. In this regard high surface temperature and dry soils are limiting factors to earthworms than low temperature and water logged soils (Kale & Kermegham, 2010). Wikipedia (2012) reported that crickets are cold blooded scavengers and feed on organic materials, decaying plant materials, fungi and some seedling plants. Low rainfall, soil moisture and high daily, diurnal and soil temperatures may have resulted in little or no decay and low microbial activity on the mulch materials at one to three MAP, hence very low cricket populations. Snail population did not respond significantly to mulch sources or trench depth at one to two MAP. This may be attributed to unfavourable soil and environmental conditions. NEARLS (2012) reported that snails are cold blooded animals and are therefore sensitive to changes in atmospheric humidity and thrive best at temperatures between 10 and 23$^0$C (Nwachukwu, 2013). When temperatures are too cold or too hot, snails withdraw into their shells, seal their shells, depend on stored food reserve in their body and aestivate (Nwachukwu, 2013). Although suitable mulch may have been available (trash, palm frond), unfavourable weather conditions adversely affected snail population in January and February 2011 (one to two MAP). However, as the rains came gradually from March (Table 4), conditions became more favourable. Generally as the rains set in and stabilized larger population of millipedes, crickets, snails and earthworms were observed in most of the plots. This phenomenon has been confirmed by many workers. Organic matter is a source of energy for soil biota and thus, influences many of the biologically mediated processes of soil (Wikipedia, 2011; Mullongy & Merckx, 1999; FAO, 2005).

### 4.2.3 Soil temperature ($^0$C) and soil moisture content (%)

The significant effect of trench depth (cm), mulch materials and their interactions on soil temperature and percentage soil moisture content may be attributed to the influence of mulch materials on soil moisture retention, conservation and soil temperature morderation.

Staufer (2012) explained that for arable soils, the most effective conservation practices are those that provide some degree of surface cover for the soil while Umass Extension (2012) noted that mulch application is one of the most effective ways to conserve soil moisture during dry season. Furthermore Clatterbuck (2010) stressed that besides keeping the moisture in the soil, mulches can also enhance soil temperature while Salau *et al.*, (2003) reported that mulching reduces soil temperature, increases soil life, in-filterability and water retention in the soil. Also Staufer (2012) reported that plastic mulches are completely impermeable and therefore prevent soil evaporation and limit water losses and erosion via the soil surface. This may be the reason why deepest trenches mulched with black polythene retained the highest soil moisture in the trenches at 0-15cm depth from the base of the planting holes at one to three MAP. (Jan-Mar, 2011).

### 4.2.4 Late season plantain growth parameters

#### 4.2.4.1 Percentage sucker sprout

The significant influence of mulch materials, and the interaction of trench depth and mulch sources on percentage sucker sprouting of plantain at three MAP agreed with Shiyam *et al.* (2010), Obiefuna *et al.* (2014) and Obiefuna (1985) who reported that mulching enhances growth and increases bunch yield in both plant and first ratoon crops in plantain. Furthermore according to Obiefuna (1986), the use of quality late sword suckers which are vigorous and healthy enhanced late season plantain establishment. Generally, with the exception of shallow (60cm) trenches mulched with trash and pam frond and all control plots, all other trenches recorded more than 50% sucker sprout respectively. The 100% sucker sprout which was recorded in 80-100cm trenches mulched with black polythene may be due to the moisture conserving property of polythene sheets when used as mulch. This agreed with Wikipedia (2013) and Staufer (2012) that plastic mulches are impermeable to water and therefore reduce the amount of water lost from the soil due to evaporation and erosion (Staufer, 2012). This means that enough water will be conserved for sucker sprouting and pre-floral growth. The probable prevented evaporation also has a secondary effect, reduced rise of water containing salt, barrier to soil pathogens and germination of some annual weed seeds (Wikipedia, 2013).

#### 4.2.4.2 Pseudostem height (cm), girth (cm), number of leaves, LA, LAI, and number of suckers.

The significant response of late season plantain growth parameters (pseudostern height (cm), girth (cm), number of leaves, leaf area ($cm^2$), leaf area index and number of suckers) to mulch materials at six, nine MAP and at harvest may be attributed to the beneficial effects and nutrient content of poultry manure and different mulches on plantain. The superiority of poultry manure over other organic manures as soil amendments has been confirmed by many authors (Follet *et al.,* 1981; Hseih & Hsu ,1993; Junadasa *et al.*, 1997) that poultry manure application increased pH, organic matter content, available phosphorus, exchangeable cation and micronutrients and decreased soil salinity and extractible irons. Soil organic matter probably increased, decomposition, microbial activity and nutrient immobilization increased (Tien *et al.,* 1994; Giller *et al.,* 1997). Babalola *et al.* (2000) also noted that poultry manure when used as fertilizer usually stimulated microbial activities thereby enhancing the release of organic nitrogen and phosphorus, nitrogen is an essential nutrient for vegetative crop production.

Organic matter is essential for plantain cultivation (Swennen, 1990). However according to Obiefuna (1985), the vegetative growth phase of plantain tolerates severe moisture stress without an appreciable yield reduction. Thus availability of appropriate mulch could limit the use of irrigation in plantain production (Obiefuna, 1987). Organic mulches have been reported to conserve moisture, maintain uniform soil temperature, add organic matter to the soil, improve soil water infilterability, reduce soil compaction, add nutrients to the soil, improve soil biological activity and improve root growth (Williams, 1997; Anderson, 1993.). According to Umass Extension, (2012), mulching is an excellent horticultural technique that is beneficial to all plants in the garden and particularly useful during dry period.

Obiefuna (1985) noted that the effect of mulching in promoting plantain growth and yield may not be limited to moisture conservation since at the peak of the rains, mulching still exhibited significant influence on growth and yield of plantain. Shiyam *et al.* (2010) corroborated this and reported that mulching enhances vegetative growth and increases bunch yield in both first and second year crops in plantain.

Compared to the control, plantains in mulched plots performed better in terms of pseudostern height, girth, leaf production, leaf area (LA), leaf Area Index and sucker production. Although the trenches mulched with black polythene sheet recorded 100% survival and sucker sprout at three MAP, they produced shorter plants with thin pseudostern girth, few and narrow leaves and very few number of suckers. Infact, the shallowest trenches produced no suckers at all and therefore no ratoon plants. Deepest trenches mulched with polythene sheets produced few suckers that were aborted. This may be attributed to the conservation of excess water at the rooting zone of the plantain as the rains stabilized, which negatively affected the physiological process at the rooting zone. While the moisture at the rooting zone was not evaporating (Wikipedia, 2013; Staufer, 2012), more water was collecting at the base of the plant in the trenches. This is corroborated by Shane *et al.* (2004) who noted that the planting depth is critical for trees and if the tree is planted too deep, this will result in poor growth of trees. Wikipedia (2013) also noted that the effect of mulch upon soil moisture content is very complex. Mulch forms a layer between the soil and the atmosphere which prevents sunlight from reaching the soil surface, thus preventing evaporation. Clatterbuck (2010) reported that excessive mulch and very deep planting of tree crops leads to accumulation of excess moisture in the rooting zone thereby making roots more susceptible to rot, insects and diseases. The combination of poultry manure at the rate of $10tha^{-1}$ and perforated plastic film spread over the manure deep in the trenches must have resulted in a similar scenario especially at the peak of the rains. This may have led to poor aeration and unavailability of oxygen at the rooting zone, resulting to restricted oxygen exchange with the plantain roots (Catterbuck, 2010) and reduced growth. Green Earth (2010) confirmed that standing water especially in cool weather will cause root rot in bananas (genetic relative of plantain); root rot from cold wet soil is by far the biggest killer of banana plant in temperate regions (Green Earth, 2010). Bananas rarely retain their full genetic potential for yield due to limitation imposed by water (Turner, 1995). The banana plants sensitivity to any form of stress imposed by moisture is reflected in changes in reduced growth through reduced stomata conductance and leaf size (Kallarackal *et al.,* 1990; Turner, 1995), increased leaf senescence (Batalgia, 1980), ultimately limiting the plant's photosynthesis (Bonhert & Sheveleva, 1998). Bananas are susceptible to saturated soil and free water, so areas where frequent flooding or water logging occurs should be avoided (Ramirez *et al.,* 2011).

The poor growth of plantains in unmulched plots at every stage of growth may be attributed to the reduced ability of plantain to cope with moisture stress during the dry season due to absence of adequate protection and additional nutrients from organic mulches, although they were manured with $10tha^{-1}$ of poultry manure. Although Obiefuna (1985) reported that the vegetative growth phase of plantians tolerates severe water stress without an appreciable yield reduction, Turner (1995) noted that banana pseudostern girth and leaf emission are sensitive to water deficits. Results on the effect of drought on plantain growth showed that drought stress reduced pseudostem height and girth in all cultivars used (Bonhert & Sheveleva, 1998). Therefore water stress reduced pseudostern height, girth, sucker production and increased loss in green leaf area in unmulched plots. Drought, salinity and low temperature affect uptake and conductance of water (Bonhert & Sheveleva, 1998). Boyer (1982) also reported that drought (assumed to be soil and/or atmosphere water deficits) in conjuction with coincident high temperature and radiation poses the most important environmental constraint to plant survival and to crop productivity.

Results showed that at six MAP, trench depth was significant ($P<0.05$) on late season plantain pseudostem height (cm). In all the treatments, deepest trenches produced taller plants than the shallower trenches at six MAP. But as the rains became heavier towards the second peak period of the rainy season (September 2011) at nine MAP, plantains in shallower trenches became taller than those in deeper trenches except in control (manured but unmulched) plots. This may have been as a result of the presence of bulk and slowly decaying organic manure (poultry manure at 10 t $ha^{-1}$) and mulches, especially saw dust and wood shavings, and the accumulation of excess moisture at the rooting zone of plantains in deepest trenches. The shallower trenches may have experienced higher rates of evaporation and organic matter decomposition due to higher daily and diurnal temperatures, more available oxygen at the rooting zone (Clatterbuck, 2010), leading to greater availability of nutrients to the plantain roots. Under water logged (i.e anaerobic) conditions, anaerobic or "sour" mulch materials that have not been properly composted have pungent odours that build from the production of alcohols and organic acids. These compounds can be phytotoxic to young plants (Clatterbuck, 2010). However, certain woods or bark also contain tannins and other extractives that may have more or less toxic influence on plants and soil micro organisms (Wikipedia, 2013). Organic mulches vary in their C:N ratio (Obiefuna *et al.*, 2014). The high C:N ratio of saw dust and wood shavings makes the mulches difficult to degrade by termites and microbes (Whiting *et al*., 2011), making them stay longer on the soil than palm frond and trash which were rapidly degraded by termites at one to three MAP. Wood chips may take as long as ten years to decompose (Whiting *et al.*, 2011) because they decompose slowly.

At harvest, plantains in shallower trenches except those mulched with trash and palm frond became taller, large and produced more leaves, but this trend was not observed in leaf area and leaf area index. These changes may have been induced by significant ($P<0.05$) influence of mulch materials and rate of degradation. Organic mulches decay overtime and are temporary, the way a particular organic mulch decomposes and reacts to wetting by rain and dew affects its usefulness (Wikipedia, 2013). Since palm frond and trash were rapidly degraded, and organic matter is a slow release fertilizer (Alagba *et al.*, 2014), plantains in deepest trenches mulched with palm frond and trash, despite the water accumulated in the trenches must have had more available plant nutrients, greater water infilteration in the soil, greater oxygen circulation and reduced temperature fluctuations due to termite galleries in those plots (Salau *et al.*, 1992; Wikipedia 2012, Obiefuna, 1995; Clatterbuck, 2010; Becker, 2003). Wikipedia (2012) reported that termites are responsible for removal of up to 100% herbaceous matter, while Becker (2003) noted that because of the large number of termites in a colony, timber, leaf or any other preferred food, once under attack, may be quite rapidly destroyed. Mommer (2003) also reported that soils surrounding termite nests or mounds have a massive increase in fertility due to higher nutrient status of the materials eroded from mound surfaces. This may be responsible for the higher values for vegetative growth parameters obtained in plots mulched with trash and palm frond at six MAP.

The consistently high values obtained for pseudostem height, girth, leaf number, L.A, LAI and sucker production in shallower plantains mulched with wood shavings and saw dust may be due to the beneficial effect of these mulches on soil properties and plantain growth.

The quantities of soil nutrients and other soil fertility indices decreased with depth and while soil acidity increased with depth (Onwermadu *et al.*, 2007). Therefore the significantly high values obtained for growth parameters at 60-80cm depths may be due to treatment effect. Wikipedia (2013) recommended that wood residues should be utilized for humus maintenance wherever it is economically feasible to do so. Furthermore, saw dust reacts much as chips, shavings, and bark, except that decomposition is more rapid in the more finely divided material. Saw dust and wood shavings have been reported to improve structure and aeration in heavy soils (Staufer, 2012), increase water absorption and infiltration and conserve moisture through weed control and reduced evaporation (Clatterbuck, 2010). Wherever locally available at low cost, wood products used as mulch can effectively replace relatively more expensive mulch material (Staufer, 2012). Obiefuna (1986) advocated for the use of saw dust as mulch in plantain because of its sufficiency, cheapness, availability and slow rate of decomposition. While these products have little or no fertilizing value, when properly used and supplemented with other organic soil amendments, they are proving beneficial to intensive farming in many ways (Shane *et al.,* 2004).Wikipedia (2012) reported that there is reduced acidification, increased contents of exchangeable calcium, thus enhancing root growth and uptake of phosphorus when regular applications of organic matter is maintained. Salau *et al.* (1992) explained that organic mulches (elephant grass and wood shavings) maintained more favorable physical and chemical soil properties than synthetic (plastic) mulch or unmulched treatments. Furthermore, at 5cm depth, the mean monthly temperature and soil water infilterability was highest under wood shaving mulch. In an experiment to determine the effect of locally abundant crop reduces as organic surface mulches on the physical, chemical and microclimate characteristics of a tropical ultisol for enhanced plantain production, Obiefuna (1991) noted that wood chips, saw dust, palm bunch refuse and to a lesser extent, cassava peel developed high moisture retention, reduced diurnal soil temperature, improved soil acidity and availability of critical macro elements of nitrogen, potassium and phosphorus necessary for plantain production. The same mulches except cassava peels exhibited a slow annual rate of biodegradation under high tropical relative humidity and temperatures.

The significant variations in LA and LAI at harvest may be attributed to proper nutrition, beneficial effects of mulching and effects of environmental factors at the time of harvest.A good nutrient supply at an early stage is required to develop an effective leaf area index (LAI) which in turn promotes growth and bunch yield in plantain (Norman *et al*., 1996). Obiefuna (1989) corroborated this report and noted that fertilized and mulched plantains not only proliferated leaves faster but also enhance leaf longevity over plantains which were manured but unmulched.

The largest LA and LAI at harvest which was recorded in medium (60 x 60 x 80cm) plots mulched with wood shavings may be attributed to the time of harvest and the beneficial effects of wood shavings mulch. These plantains flowered in 308.80 days (early October, 2011) and were harvested at twelve MAP (December 2011). This period of flowering was very close to the second peak of the rainy season (Nwosu and Adeniji, 1980), while harvest coincided with the onset of the dry season as reported by Nwosu and Adeniji (1980) who noted that the dry season in south eastern Nigeria starts in mid November and ends in mid March., Obiefuna & Ndubuizu, (1983) explained that as the dry season progressed, leaf number in plantain reduced to one or three battered leaves. This leaf reduction in the dry season may have been caused by reduced rate of leaf formation due to drought and other adverse weather conditions. Hsiao and Xu (2000) pointed out that leaf growth is severely inhibited at the onset of drought while leaf cell expansion during water stress is regulated by changes in pH and inhibition of growth is mediated by a rapid decrease in extensibility of expanding leaf cell walls (Munns *et ai.,* 2000). Sudden environmental charges bring about rapid and often transcient changes in leaf elongation rate (Munns *et al.,* 2000) and such environmental changes include light intensity, soil water potential caused by changes in salinity (Cramer & Bowman, 1991), and humidity (Parish and Wolf, 1983; Schackel *et al*., 1987). The speed of the response suggests that it is changes in leaf water status that drive the initial change in elongation rate presumably mediated by changes in tugor (Munns *et al,* 2000). This may have been responsible for the reduced number of leaves in all treatments from nine MAP to harvest. The time of harvest of plantains in medium (60x60x80cm) trenches mulched with wood shavings coincided with the start of the second dry season (December, 2011) during which time environmental and soil moisture conditions were still favourable. This may explain the largest number of leaves, LA and LAI at harvest.

According to Manuela *et al.* (2003), water loss in plants is minimized by closing stomata and among other features, decreasing canopy leaf area through reduced growth and shedding of leaves. This phenomenon has been observed in plantain during the dry season as reported by Ndubizu & Obiefuna (1982). This may explain the reduced number of leaves in other plots and the least number of leaves recorded in unmulched plots at harvest, although they produced relatively higher number of leaves at the second dry season. This may have been due to beneficial effects of poultry manure (10 t $ha^{-1}$) and application of different mulches.

**4.2.5 Late season plantain crop protection**.

The absence of black Sigatoka disease in late season plantain at six MAP and the significant response of plantains to the disease severity due to mulch materials, trench depth and their interaction at nine MAP may be due to the time of planting, beneficial effects of poultry manure, different mulches, as well as pattern of infestation of the disease. Although black Sigatoka has been reported to be most severe on susceptible plantain cultivars under conditions of high rainfall and humidity (Swennen, 1990), generally infestation was low at nine MAP which coincided with the second peak of the rainy season (Sept. 2011). This may be attributed to proper nutrition enhanced by the application of poultry manure at 10 $tha^{-1}$ and application of different mulches. This report was confirmed (Alagba, 2010; Obiefuna, 1986). Alagba (2010) reported that black Sigatoka leaf spot disease was significantly controlled in both sole plantains and plantains intercropped with kola varieties at poultry manure rate of 10$tha^{-1}$due to increased mineralization of nutrients in poultry manure and their subsequent availability to plantain with increased rainfall, soil moisture and optimum soil temperatures which led to a boost in growth and disease resistance of plantain. Ihejirika *et al.* (2009) corroborated this report and noted that soil amendment with poultry manure at 5, 10 and 20 t $ha^{-1}$ influenced field diseases of kola. Furthermore, the higher resistance in plantains under higher poultry manure rates may be attributed to the fact that poultry manure possesses the capability of ecological production management system that promotes and enhances biodiversity; biological cycles and soil biologically mediated activities (Wikipedia, 2011; Mullongy & Merckx, 1991; FAO, 2005) that encourage nutrient availability for healthy growth of crops (Ihejirika *et al.*, 2009). This restores, maintains and enhances ecological harmony (Cummis, 2000). It also decreases soil salinity and extractible ions immobilization (Tian *et al.*, 1994; Giller *et al.*, 1997). All these provide an unconducive environment for disease prevalence, symptom manifestation and spread (Ihejirika *et al.*, 2009; Tian *et al*., 1994). Low severity of field diseases encourages high yield of many field crops as they respond to organic manure (especially poultry manure) (Ihejirika *et al.*, 2009) and organic mulches. Apart from the fact that proper manure enhances crop yield in most soils (Maynard, 1991), it also sustains plants capability to resist disease attack and the superiority of poultry manure over other manures has been confirmed in many experiments (Follet *et al*., 1981). Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures (Marappan and Narayanana, 1993).This may also explain the higher but moderate severity of black Sigatoka leaf spot disease in control (manured but unmulched) plots, the significant response of late season plantain to leaf damage severity by *Zonocerus variegates* at harvest and its absence at six and nine MAP. Although trench depth (cm), mulch materials and their interaction had no significant influence on response of plantain to black Sigatoka disease at harvest, there was a general decrease in disease severity. This may be attributed to favourable environment and proper nutrition. Also the harvest time of the plantain in some of the various treatments coincided with the second dry season (December 2011 to March 2012) accompanied by drier weather and lower relative humidity and rainfall which do not favor the prevalence of the disease.

The weed dry weight measured at six, nine MAP and at harvest responded significantly to mulch materials and the interaction of trench depth and mulch materials at all stages of growth. The results implied that high weed biomass at the first sampling could be due to absence of enough canopy cover from plantain. The significantly reduced weed infestation at the nine MAP and harvest was enhanced by canopy development of plantain which helped to suppress weeds due to the beneficial implication of mulching, favourable environment and depth of planting. Anderson (1996) reported that weeds in plantain can be controlled through mulching, use of herbicides and manually. While Obiefuna (1989) reported that it is feasible to control weeds in plantain biologically using egusi melon, Swennen (1990) found mulching as the most efficient weed control technique because a mulch layer suppresses or prevents weed growth. Decoteau *et al.* (2005) noted that various cultural practices and environmental factors have profound effects on crop development resulting in modified overall leaf canopy structure and appearance. The beneficial effects attributed to the use of mulches appear directly related to the changes in plant microclimate (Decoteau *et al.,* 2005). Alagba *et al.* (2014) reported that application of poultry manure to plantain at 10 t $ha^{-1}$ significantly ($P<0.05$) reduced weed incidence in both monoculture plantain and intecropped kola/plantain plot.

### 4.2.6 Reproductive and yield parameters of late season plantain

Trench depth (cm), mulch materials and their interaction had significant effect on all reproductive and yield parameters of late season plantain as has been confirmed by other researchers (Obiefuna 1991; Emma-Okafor, 2010). This may be attributed to the time of planting, quality of planting materials used, and positive influence of mulches on soil properties, crop growth and yield and favorable influence of deep planting. Obiefuna (1986) reported that plantains established between July and December produced significantly ($P=0.05$) higher and sustained yield and matured in unfavorable weather only once in every three crop harvest cycle. Furthermore optimum 3 crop total plantain yields were obtained when the suckers were planted in August-December. Emma-Okafor (2010) corroborated this report and noted that days to 50% flowering in late season plantains was influenced by manure rate and time of planting.. Furthermore, flowering in mulched and manured plots was significantly earlier than in manured but unmulched (control) plots. This could be due to availability of more nutrients due to mineralization of organic mulches used, as well as moisture conserving benefits of mulching on soil.

Plantains in 60x60x80cm trenches mulched with wood shavings were the earliest to flower (308.80days), closely followed by plantains with the same mulch in 60x60x60cm trenches (372.00 days). This may be due to combined beneficial effects of wood shavings and favourable environment. Although plantain has been reported to be adversely affected by water stress especially during the flowering stage (Obiefuna, 1985), plantains planted in 60x60x80cm trenches and mulched with wood shavings flowered shortly after the second peak of the rainy season (early October, 2011) during favourable weather, developed greatest number of leaves and effective LAI. This in turn promoted good growth and subsequent fruiting towards the start of the dry season.

Late sword suckers have been reported to produce plants which significantly (P=0.05) flowered earlier than those from early sword suckers, maidens, peepers and bits (Obiefuna, 1983). Deepest plantings seemed to delay flowering in all treatments while plantains inmedium trenches (60x60x80 cm) flowered earliest in all the treatments. The time to 50% flowering in plantains mulched with trash coincided with the second dry season (December – March, 2012) during which time plantains had to depend on available soil moisture. It is possible that combined effect of mulching on moisture conservation, moderate or reduced evaporation in 60x60x80cm trenches of mulched plots, more available oxygen at the rooting zone (Staufer, 2012*;* Salau *et al.,* 1992) and lower temperature fluctuations (Clatterbuck 2010; Salau *et al.*, 1992) offered by mulching, as well as supply of available nutrients mineralized from organic mulch stimulated earlier flowering in plantains in medium trenches (60x60x80cm). Nutrient stress (Simbawama *et al.*, 1994) and exposure of plantain to supra-optimal soil temperatures in unmulched plots (Obiefuna, 1985) may have caused poor growth and delayed flowering in such plots.

The significant response of late season plantain bunch weight (t $ha^{-1}$), number of hands/ bunch  and number of fingers/bunch to trench depth (cm), mulch materials and their interaction maybe attributed to the inter play of type of planting materials used, influence of mulching and application of recommended dose of poultry manure (10 t $ha^{-1}$) at each depth of planting. Obiefuna (1985) noted that plantain sword suckers taken from the orchard and planted in the dry season (November-March) were apparently pre-conditioned to the adverse whether while still attached to the mother plant. Consequently the suckers planted in the dry season sprouted during the next rain with accelerated growth, resulting in early maturity, simulating the widely practiced dry season planting for yams. Suckers planted in October-

December matured earliest and in weather with non-limiting moisture and high insulation and so produced significantly heavier bunches and longest number of marketable fingers (Obiefuna, 1983). Nweke *et al*. (1988) and Ogazi (1996) reported that in intensively managed backyard and home gardens, yield of plantain is high and continuous (estimated 30-50 t $ha^{-1}$), due to large quantities of organic matter thrown around the plantain mat. Obiefuna (1987) reported that yield of late season plantain was significantly higher in mulched than in unmulched plots. Alagba *et al.* (2014) also confirmed this report and stated that application of poultry manure at 10-20 t $ha^{-1}$ significantly improved growth parameters in Cola varieties and plantain yield in both mono culture plantain and intercropped plots of kola/plantain.

Relatively high yields obtained in 60x60x60 cm and 60x60x80 cm plots mulched with wood shavings and 60x60x60cm plots mulched with saw dust have been confirmed by other workers. Increased yields following use of saw dust mulch in strawberries.was due to the fact that after decomposition had proceeded several years, the resulting increase in humus- like organic matter gave the soil an improved porous sponge structure, greater usable moisture capacity and better aeration (Clatterbuck, 2010). Although some of the plantains flowered at the onset and during dry season, the effect of the stress induced by higher temperature and low rainfall was cushioned by mulching. The temperature for foliar development of plantain is 26-28$^{0}$C (and for fruit development is 20 – 30$^{o}$C (Ganry, 1980). Obifuna (1991) reported over 60% yield increase in plantain mulched with wood chips, saw dust and palm bunch refuse, bridging the recurrent wide peak (scarce) production gap.

According to Bhattachrayya & Rao-Madhava (1985), soil covers are beneficial to the plantation crops such as plantain because of their capacity to conserve moisture and make the moisture available over a longer period. IITA (1981) reported yield increase of about 400% in mulched plantain over that of unmulched fertilized plot over 4years, which confirms the results of this research. Generally plantain bunch weight ($tha^{-1}$), marketable fingers/bunch and marketable hands/bunch were significantly higher in mulched than in unmulched and manured plots. Obiefuna (1988) and Wilson (1987) also corroborated the fact that heaviest bunches and highest number of hands and marketable fingers were obtained in saw dust mulched plots. The marketability of plantain is a function of number of marketable fingers/ hand and hands/bunch. Larger fingers and fuller hands result in heavier bunches and higher prices. This report was corroborated by Shaibu *et al.* (2012) who noted that in plantain and banana, weight of a bunch is determined by the total number of hands and fingers produced per bunch. Therefore the weight in kilograms is a function of the total number of hands and fingers (Shaibu *et al.*, 2012) and weight of the fingers (Ndubuizu *et al.*, 1983). Therefore this explains the fact that the greater the number and weight of hands/bunch and marketable fingers/bunch the heavier the bunches. .

**4.2.7 Growth parameters of first ratoon crop of late season plantain.**

The significant response of late season plantain first ratoon pseudostern height (cm), girth (cm), leaves, suckers, leaf area (LA) and leaf area index (LAI) at harvest to mulch application may be attributed to the fact that mulching has positive beneficial residual effect on vegetative growth of crops, especially in conjunction with other organic manures in both plant and first ratoon crops. In plots mulched with palm frond and trash which have low C:N ratio; there was good nutrient supply in time to the plant crop due to rapid degradation by soil organisms. This may be responsible for slightly reduced height; girth, leaves LA, and LAI of the first ration: crops. However, plantains in deepest trenches mulched with palm frond and trash seemed to exhibit a reversal of the growth parameters observed in the plant crop. At harvest, taller and larger first ratoon plants emerged from deepest trenches than shallower trenches mulched with palm frond and trash. Although the mulches were rapidly degraded (Obiefuna 1985; Obiefuna *et al.*, 2014), and the mulches unreplenished, the presence of poultry manure which is a slow- release manure must have compensated by releasing critical macro and micro nutrients in these trenches which were made available to the plantain roots. Furthermore, deeper trenches may have conserved more moisture than shallower trenches especially during the second dry season. Also the earlier activities of termites which produced galleries in the soil improved water infiltration, root penetration and more available oxygen in the rooting zone (Clatterbuck, 2010; Wikipedia, 2013; Becker, 2003).

The significant response of late season first ratoon crop growth parameters (number of leaves, number of suckers, LA and LAI) to the interaction of mulch materials and trench depth at harvest may be due to residual influence of organic manure, mulching depth of planting. The rate of decay of mulches varies with the mulch source and determines to a large extent the rate of mineral nutrient release cycle and availability to crop (Obiefuna *et al.,* 2014). As noted earlier, organic mulches decay over a long time especially saw dust and wood shavings and add nutrients to the soil (Staufer, 2012). The slow release of nutrient from poultry manure in all plots and added advantages of mulching may be responsible for sustained relatively high growth parameters and little variation (decrease) in comparison to plant crop in plots mulched with saw dust and wood savings.

The significantly lower growth parameters and  obtained in control plots and zoro values obtained in plots mulched with black polythene has been confirmed in plantain (Obiefuna, 1984; Obiefuna *et al.,* 2014; Swennen, 1990; Robinson, 1996; Emma-Okafor, 2010; Obiefuna, 1989), tomatoes (Decoteau, 2005), mustard, (Awal and Sultana, 2011), plantain and cocoyam (Shiyam *et al.*, 2010). Black polythene (plastic) mulches have been effectively used to control or suppress weed growth (Wikipedia, 2013). Since the perforated black polythene sheet was spread around the base of the plantain, it may have also suppressed spouting of suckers due to reduced air circulation below the mulch layer, heat generated in trenches and impenetrability of the material, effectively suppressing sucker sprouting. This may be responsible for sucker abortion in shallower and deepest trenches, hence lack of ratoon crops and 0.0 (zero) values of the growth parameters in those plots. Wikipedia (2013) reported that mulch can also prevent water from reaching the soil by absorbing or blocking water from light rain. Staufer (2012) reported that plastic mulches are completely impermeable, they therefore prevent direct soil evaporation and limit water losses and erosion via the soil surface.

The continuously highest vegetative growth parameters obtained in late season plantain first ratoon crops mulched with wood shavings in medium trenches (60x60x80cm) and shallow trenches (60 x 60 x 60cm) mulched with saw dust and wood shavings have been confirmed in plantain (Shiyam *et al.,* 2010; Obiefuna, 1985; Obiefuna *et al.,* 2014) and other crops in general (Wikipedia, 2013). Accordingly, these mulches have a high C:N ratio, they stay longer on the soil surface, conserve water and make available nutrients at the time of decay.

The residual effect of indigenous mulches may add organic matter and some plant nutrients into the soil (Cadavid *et al.,* 1998; Leblac *et al.,* 2006; Youkhana & Idol, 2009). Awal and Sultana (2011) reported that among indigenous mulches used, saw dust mulch produced tallest crops in mustard while straw mulches produced the shortest plants. Saw dust also produced plants with highest number of branches per plant, and broadest LAI, compared with those mulched with straw, ash and control plots.

Non significant effect of trench depth on sucker production may be due to the use of uniform sword suckers as planting materials. Bekhiet *et al.* (2003) had observed differences in the time to plantain corm germination with different planting materials.

#### 4.2.8 Late season plantain first ratoon crop protection.

The non-significant but good response of first ratoon crop of late season plantain at harvest to black Sigatoka leaf spot disease severity as influenced by trench depth, mulch materials and their interaction may be due to time of planting and proper nutrition offered by residual influence of organic manure and mulching. Although there was no significant variation among treatment means, the severity of the disease was low. Ihejirika *et al.* (2009) had earlier reported that pest and diseases are repelled from well nourished and healthy plants. Furthermore, the time of harvest of some of the plantain followed the same cycle with the parent crop, coinciding with third dry season which does not favour disease incidence and prevalence of black Sigatoka leaf spot disease.

### 4.2.9 Reproductive and yield parameters of first ratoon crops of late season plantain.

The days to 50% flowering in first ratoon crops of late season plantain followed the same pattern with plant crop. Plantains in 60x60x80 cm trenches mulched with wood shavings were the earliest to flower. This pattern was also observed in yield parameters (bunch weight in t $ha^{-1}$, number of hands/bunch, fingers/hand and fingers/bunch). The significant variations in yield and yield attributes in first ratoon crops of late season plantain in response to mulch materials and the interaction of mulch materials and trench depth may also be due to the interplay of the effect of mulch sources, depth of planting, environmental factors, residual effects of organic manure and quality of planting material. Obiefuna (1985) explained that saw dust mulched plots in late season plantain significantly gave higher yields than those mulched with other organic mulches in plant and first ratoon crops. In a nutritional study on bananas, increases in bunch yield in mulched plots were attributed to favourable soil physico-chemical and biotic conditions. On the other hand, the yield decline observed in control plots and those mulched with black polythene may be a direct response to soil fertility decline and relative suppressive attributes of plastic mulch on plantain sprouting, establishment and growth. Shiyam *et al.*(2010) also reported that mulched and manured plots had better yield in the ratoon crop than plantains in control plots and those fertilized but not mulched. Bunch yield, (t $ha^{-1}$) hands/bunch, fingers/hand and fingers/bunch were highest in

60x60x80 cm trenches mulched with wood shavings closely followed by shallow trenches mulched with saw dust and deepest trenches mulched with trash, respectively. Time to 50% flowering and subsequent harvest was significantly influenced by mulch materials and the interaction of mulch sources and trench depth. The variations may be due to effect of environmental factors, time of planting and different mulches on plantain phenology. Early sucker proliferation in response to good nutrition and favourable environmental factors may have been as a result of early and fast growth of the mother plant and first ratoon crops in plots mulched with wood shavings and saw dust. Although all plantains were planted in December, variation in time to 50% flowering may be due to varying influences of mulches and planting depths. This results obtained have shown that the ratoon crops in medium trenches mulched with wood shavings and those in shallow trenches mulched with saw dust followed the same growth and yield pattern as the plant crop. The plantains in deepest trenches mulched with palm frond and trash produced yield almost similar to the plant crop but higher. This was confirmed by Turner (1994) who postulated that ratoon crops are potentially more productive because they benefit from the residual effect of previous crops and that yield decline is associated with infection with pests and diseases.

This result obtained from trash mulched plots confirmed earlier reports by Obiefuna (1986) that there were conflicting reports of plant crop yields being greater than, equal to or less than first ratoon yield. Although yield decline was observed in other treatments, it was minimal compared to earlier reports of over 25% yield decline in plantains planted at the conventional onset of the rain in South eastern Nigeria as reported by Obiefuna (1985).

**4.2.10 Total yield of late season plant and first ratoon crop of plantain.**

The highly significant influence of mulch materials and the interaction of mulch materials and trench depth on total crop yield of late season plant and first ratoon crop has been confirmed by other researchers. Application of mulch in desert banana plantation has been reported to improve crop nutrient availability and soil physical properties, resulting in improved root growth and subsequent yield increase (Salau *et al.*, 1992). Obiefuna *et al.* (2014) reported that mulching and organic production system is the advocated remedy for plantain yield variation. The mulch materials effectively conserved moisture in the second and third dry season, creating favourable environment for enhanced ratoon establishment and yield. The consistently higher yield in medium trenches (60x60x80cm) mulched with wood shavings and shallow (60x60x60cm) trenches mulched with saw dust respectively had been confirmed by Obiefuna *et al.* (2004) who noted that because of high C:N ratio of wood shavings and saw dust, crop yield is adequately compensated by relatively high ratoon yields.

#### 4.2.11 Late season plantain high mat

The significant influence of trench depth (cm) on the height (cm) of the plantain mat may be attributed to the growth habit of plantain, type of mulch used and the rate of mulch decay and availability nutrients to plantain roots. In plantains successive ratoons form progressively nearer the soil surface with the consequence that while shallow planted plantain crops may give good yields, the ratoon crops yield around 30% less because of uprooting by wind (Obiefuna,1983). The implication of the height of the plantain mat is that the higher the plantain mat, the more exposed the shallow roots of the plantain to drying, the more susceptible the psuedostem to wind damage, toppling and uprooting. Obiefuna (1983) reported that plantains are susceptible to soil erosion or soil wash caused by water running down the psuedostem. This is more pronounced in shallow rooted plantains which results in uprooting due to poor rooting system as the rhizomes became exposed. According to Obiefuna *et al.* (2014), the plantain root distribution in response to different mulches showed significantly more plantain roots in top soil (0-15cm) than in sub soil (15-30cm). This root distribution is in response to mulch/manure nutrient availability. Nutrients move to plant roots by mass (bulk) flow and diffusion. In addition, as roots grow through the soil, they come in direct contact with and intercept nutrients associated with soil particles that are displaced by roots (Adler *et al.*, 2012). The quantity of nutrients absorbed by plant roots through root interception depends on the soil volume occupied by the roots, the concentration of nutrients in the soil, and the root morphology (Adler *et al.*, 2012). The resulting concentration gradient that forms from the bulk soil to the root surface causes nutrients to diffuse along that gradient towards the root surface. Conversely, elements delivered to the root surface in excess of plant demand establish a concentration gradient away from the root surface and diffusion is then away from the plant root (Adler *et al.*, 2012).

The top soil forms an interphase with the mulch materials.This stimulates root growth towards the mulch/soil interphrase in response to nutrient release and availability. Therefore the height of the plantain mat may determine the susceptibility of the plantain roots to dying out, wind damage and toppling especially during drought and heavy thunder-storms (Obiefuna, 1985).

. The advantage of deep planting of plantain is that it is the inverse of hilling up (Obiefuna, 1983) producing plantain less susceptible to root damage (Obiefuna, 1983). It also implies that it may take the plantain mat a longer time to rise to the soil surface, protecting the plantain roots for a longer period, giving rise to more productive stools. Generally the deeper trenches produced higher mats in all the treatments. This may be attributed to the response of plantains in deepest trenches to light. The plantain mat is negatively geotropic.The deepest trenches probably created a dark environment for the suckers (which are stems) which made plantains to grow away from deep planting and respond faster towards light resulting in higher mats.

The significant influence of trench depth (cm) and mulch materials on the rate of rise of the plantain mat (cm/month) may be attributed to the varying nutrient release rates of different mulch manures in plantain growth as well as rate of sucker formation. The palm frond and trash mulches which were rapidly degraded made plant nutrients more available to plantain roots faster and earlier. This may have stimulated a more rapid initial plantain root growth in these plots in response to nutrient availability, and consequent higher rate of rise in plantain mat especially in medium and deepest trenches. Saw dust and wood shavings which were degraded at a slower rate due to their high C:N ratio (Obiefuna *et al.,* 2014) must have stimulated a less rapid initial root growth, hence the lower rate of rise in plantain mat growth. While the rate of mat growth in saw dust plots was 1.24 cm/month in 60x60x60 cm plots, 1.39 cm/month in 60 x 60 x 80 cm trenches and 1.74 cm/month in deepest trenches of 60x60 x100 cm plantains mulched with trash for instance produced mats which rose at the rate of 1.28 cm/month in shallow trenches, 1.73 cm/month in medium trenches and 1.74 cm/month in the deepest trenches. The highest rate of mat rise was recorded in all plots mulched with black polythene at 1.43 cm/month in shallow trenches, 1.67 cm/month in medium trenches and 1.89 cm/month in deepest trenches respectively, closely followed by those in unmulched plots. The highest rate of mat rise in trenches mulched with black polythene may have been stimulated by the added effect of the black colour to the dark environment created in the deepest trenches resulting in a more rapid response of plantains in those trenches to light.

### 4.2.12 Post experimental soil physico-chemical characteristics.

The post experimental soil physico-chemical characterization showed increase in pH and quantities of various macro and micro elements in response to mulch application and depth of planting. This result agreed with Pitram & Singh (1993). Although the mechanisms responsible for the neutralization of acidity by organic manure and mulches has not been conclusive, several workers proposed that increased pH obtained by the addition of plant material to the soil was a result of ion exchange reactions in which terminal $OH^+$ s of Al or $Fe^{++}$ hydroxides are replaced by organic anions which are decomposition products of the manure such as malate, citrate and tartrate (Bessho & Bello, 1992; Yan *et al.,* 1996; Ponkee & Summer, 1997).

However, Bessho & Bello (1992) suggested that the ability of organic manure to increase pH was due to the presence of basic cations, contained in the organic manure. The observed improvements in organic matter, exchangeable bases, exchangeable cation exchange capacity (ECEC) (in all trench depth and mulch sources applied) of residual soil nutrients status at post harvest period further confirms earlier works (Hsieh & Hsu, 1993; Juuadasa *et al.,* 1997; Obiefuna 1985; 86; Obiefuna *et al.,* 2014; Shiyam *et al.,* 2010; Awal & Sultana, 2011; Staufer, 2012; Clatterbuck, 2010; Wikipedia, 2012; 2013; Alagba *et al.,* 2014; Emma-Okafor, 2010; Follet *et al*., 1981) that the residual effect of manures and mulches especially poultry manure and organic mulches could last well into the third or fourth year of cropping (Gupta *et al.,* 1997) or up to 10 years when saw dust or wood shavings are used (Clatterbuck, 2010). Obiefuna *et al.* (2014) noted that soil physico-chemical characteristics were improved when organic mulches (saw dust, wood chips, palm bunch refuse, trash, palm fibre) were used in mulching late season plantains while Alagba *et al.* (2014) confirmed increased quantities of soil nutrients at post harvest period with application of 10-20 $tha^{-1}$ of poultry manure to sole and intercropped plots of kola and plantain.

The deepest trenches mulched with black polythene recorded the highest residual $Ca^{2+}$ (3.20 cmol $kg^{-1}$) and exchangeable $Mg^{2+}$ (2.40 $cmolkg^{-1}$), ECEC (7.10). This may be attributed to the impermeability of the plastic mulches leading to slower rates of leaching at the rooting zone and more available nutrients from poultry manure at 10 t $ha^{-1}$ which were conserved in the soil. The improved physical properties in response to mulch manure application has also been confirmed (Obiefuna, 1985, 86; 1990; Obiefuna *et al.,* 2014; Alagba *et al.*, 2014; Alagba 2010; Emma-Okafor, 2010), hence the improved textural classes of soils across all trench depths in response to mulch manure applied. The 60x60x60cm trenches mulched with saw dust produced the best textural class of soils (sand 76%; silt, 6.00%, clay 17.20%) as confirmed by Staufer (2012). Medium trenches recorded the highest pH (lowest acidity) in all mulches applied in late season plantain crop.

### 4.2.13 Input-output cost analysis for late season plantain plant and first ratoon crop enterprise

Plantains established in 60-80cm trenches and mulched with wood shavings gave very profitable returns. Mulching with wood shavings in 80cm trenches gave the highest financial returns (#5,779,356.39) and benefit cost ratio (5.06). All plantains mulched with palm fronds, saw dust and trash were also profitable. Generally, all mulches and trench depths produced profitable enterprises but some were more profitable than others. The use of indigenous mulches as well as different planting depths is capable of boosting revenue of resource poor famers in Southeastern Nigeria for dry season plantain production for obvious reasons. For example, the land preparation is once, weeding was reduced and plantains protected from pests and diseases. All these minimized the input cost and enhanced income to the farmer. The mulches are cheap, available and affordable by resource poor farmers. Smith *et al.* (2001) stated that the use of animal waste such as poultry manure as a means of boosting soil fertility is economically justified. Obiefuna (1991; 1983; 1986) also corroborated this report and stated that use of mulch materials for dry season plantain production significantly influenced yield and income return of plant and first ratoon crop yields.

### 4.2.14 Correlation coefficients of late season plantain growth, protection and yield parameters

Pilfering of plantain bunches is a serious challenge in plantain research. These results show that some growth parameters namely plant height, number of leaves and leaf area are good estimates of yield projection in plantain production. The high positive correlation between plantain bunch weight and number of fingers re-affirms earlier reports that finger number and weight determine bunch weight (Shaibu *et al*., 2012; Ndubuizu *et al.*, 1983). The significant negative correlation of number of suckers and days to 50% flowering explains the delayed flowering in plantain caused by multiple suckers (Robinson, 1996; Swennen, 1990). Furthermore, the negative correlation of weed dry weight with plantain bunch weight emphasizes the importance of weed management in plantain production (Robinson, 1996). Thus poor weed control results in plantain yield reduction and decline.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The current study showed that application of wood shavings at a depth of 60 - 80cm and saw dust at 60cm depth significantly enhanced late season plantain plant and first ratoon crop establishment, sucker proliferation and yield. Application of black polythene sheet mulch significantly improved sucker sprout in late season plantain (100%) but suppressed growth and yield of plant crop and resulted in death of suckers of ratoon crop in 60-100cm trenches.

Mulch application significantly eliminated black Sigatoka leaf spot disease at six MAP and reduced disease severity from nine MAP to harvest of plant and first ratoon crops of late season plantain. Weed infestation was significantly reduced by application of different mulches from six MAP to harvest of plant and first ratoon crops of late season plantain. Consistently high yields were obtained from shallow and medium trenches mulched with wood shavings and shallow trenches mulched with saw dust. First ratoon yields were slightly reduced in all treatments except in deepest trenches mulched with trash where first ratoon yields were higher than that of the plant crop. Post experimental soil properties were significantly improved in all treatments. The most profitable of all the treatments was obtained when plantains were mulched with wood shavings in 60x 60x80cm trenches which gave highest monetary returns (#5,779,356.39), followed by 60x60x60cm trenches mulched with same and 60x60x60cm trenches mulched with trash.

## 5.2 Recommendations

1. Plantains planted 60-100cm deep and mulched with 2kg/plant of wood shavings, saw dust, trash and palm fronds and polythene sheet is profitable.

2. Famers can maximize late season plantain enterprise by application of poultry manure at 10t $ha^{-1}$ , wood shavings at 2kg/ plant in trench depths of 60x60x80cm because this enterprise recorded vigorous growth and yield (20.88 t $ha^{-1}$, 16.63 t $ha^{-1}$) in plant and first ratoon crops. The production package is the most profitable in terms of monetory returns.

3. Farmers can also cultivate late season plantain in 60x60x60cm trenches, apply poultry manure at 10 t $ha^{-1}$, and mulching with 2kg/plant each saw dust, trash and palm fronds respectively. These enterprises also gave relatively high plant and first ratoon yields and monetory returns.

4. Resource poor farmers in Southeastern Nigeria should adopt the use of poultry manure at 10 t $ha^{-1}$, saw dust, wood shavings, palm frond and trash for mulching late season plantain because of their cheapness, availability, affordability and beneficial influence on soil pysico-chemical properties.

5. Although mulching with trash, palm frond and saw dust gave slightly lower yield and produced plantains that were harvested in the dry season, the enterprises were worth undertaking because of plantain scarcity and high prices. Furthermore, the hunger gap was effectively bridged among the high population. Although trash and palm fronds were rapidly degraded by termites in the first dry season, they still supported high populations of soil macro biological life (especially termites and big black ants). However, they can be replenished in the second dry season to further provide protection of plantains from drought and boost late season plantain yield.

6. Although perforated black polythene sheets recorded 100% sucker sprout in 80-100cm trenches, conserved the highest percentage soil moisture within one to three MAP, and recorded highest values for some of the soil nutrients at the end of the experiment, it should not be used by farmers as mulch in dry season plantain production. This is because plantain

growth was suppressed, suckering was either inhibited or aborted while yield was low. However, if polythene should be used, better management technology should be exploited such as removal of the polythene at the end of the dry season.

7. For effective management of the late season plantain mat, trenches of 60-80cm depth should be used because the plantain mat rose at a slower rate than the 100cm trenches. Further to this, mulching with palm fronds and saw dust in 60cm trenches produced mats that rose at the slowest rate and therefore should be adopted by farmers in south eastern Nigeria.

8. Further research should be done in this area.

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## APPENDIX

**Predominant weed species occurring in late season plantain intercrop during the period of study.**

| BOTANICAL NAME | ENGLISH NAME |
|---|---|
| *Salvinia nymphellula* | Salvinia |
| *Newbouldia laevis* (P. Beauv) | Not available |
| *Acanthospermium hispidium* | Bristly starbur |
| *Baphia nitida* | Not available |
| *Alchornea cordifolia* | Christmas Bush |
| *Marinophytom fulvum* | Not available |
| *Palistola hirsute* | Not available |
| *Cyperus rotundus* | Purple nutsedge |
| *Mariscus aternifolius* | Not available |
| *Clapertonia ficifolia* | Not available |
| *Albizia zygia* | Not available |
| *Axonopus compresus* | Broadleaf carpetgrass |
| *Dialium guineense* willd | Black Velvet |
| *Gnestis ferruginea* Dc. | |