EVALUATION OF CASSAVA PEEL BASED COMPOSTS FOR BANANA (*Musa c*avendish cv. Williams) PRODUCTION IN IBADAN, NIGERIA

BY

Stephen Adesola IPADEOLA

MATRIC No. 103349

B. Agric (Obafemi Awolowo University, Ile- Ife)

M. Sc. Agronomy (Ibadan)

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CERTIFICATION

We certify that this work was carried out by Mr. Stephen Adesola IPADEOLA in the Department of Soil Resources Management, University of Ibadan, Ibadan, Nigeria.

Supervisor

G. O. Adeoye

B. Sc. (Ife), M. Sc., Ph. D (Ibadan)

Professor, Department of Soil Resources Management,

University of Ibadan, Nigeria

Co-Supervisor

S. O. Oshunsanya

B. Agric (Ago Iwoye), M. Sc., Ph. D (Ibadan)

Professor, Department of Soil Resources Management,

University of Ibadan, Nigeria

DEDICATION

This work is dedicated to God Almighty, the only One who knows the end of a thing from the beginning. He has being my inspiration, succour and most importantly my sufficiency. He is the Alpha, Omega, and worthy to be praised.

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ABSTRACT

Cassava peel (CP) is an organic waste of cassava processing that requires extra cost to manage but it can be composted as soil amendment in crop production. However, CP is limited in bioavailable potassium (K) and often requires fortification with other organic sources for optimum performance. Mexican sunflower (MS), Siam weed (SW) and Poultry manure (PM) can be used as fortifiers to improve the fertilizer use efficiency of CP, but there is a dearth of documentation about its use as fertilizer in banana production. Therefore, the nutrient release pattern of cassava peel-based compost (CPBC), and banana growth and yield responses to CPBC application were investigated in Ibadan, Nigeria.

The CP fortified with MS, SW and PM were composted as CP (100%), CP+PM (70%+30%), CP+SW (70%+30%), CP+MS (70%+30%), CP+PM+SW+MS (70%+10%+10%+10%) and CP+SW+MS (70%+15%+15%). From each compost, 0.34 g was added to 50 g river sand weighed into75 ml incubation cup and were laid in a completely randomized design with four replications in the laboratory to study K (cmol/kg) release patterns for 10 weeks. Sand samples were collected from each incubation cup at 2, 4, 6, 8 and 10 weeks for nutrient analyses using standard procedures. The best three composts CP+PM, CP+PM+SW+MS and CP+SW+MS were selected for field trials with control in a randomized complete block design replicated thrice. On the field, the selected CPBC were applied at banana recommended rate of 600 kg K/ha and studied for 18 months using banana as a test crop. Stem Girth-SG (cm), Number of Sucker at Harvest-NSH, Plant Height-PH (cm), Number of Hands per Bunch-NHB and Bunch Weight at Harvest -BWH (kg) were determined using standard procedures. Data were analysed using descriptive statistics and ANOVA$\leq_{0.05}$.

Nutrients released were significantly different among the composts in the weeks of incubation. The highest K determined by the composts were 1.91±0.34 (CP+PM+SW+MS) at 2, 1.46±0.41 (CP+SW) at 4, 1.38±0.64 (CP+MS) at 6, 1.18±0.21 (CP+SW+MS) at 8 and 1.09±0.42 (CP+PM) at 10 weeks after incubation (WAI). The highest total N and total P determined was at 2 and 8 WAI with 2.31±0.41 (CP+PM+SW+MS) and 118.75±0.41 (CP+PM+SW+MS) respectively. The CPBC treatments significantly improved the banana growth parameters with similar SG and NSH from CP+SW+MS (14.96±0.37) and from CP+PM+SW+MS (14.29±0.31) but significantly higher than CP+PM (13.00±0.28) and control (9.66±0.37); likewise compost of CP+PM+SW+MS gave tallest plants (175.49±0.27) followed by CP+SW+MS (159.61±0.44) which was similar to CP+PM (141.93±0.34) but significantly higher than control (112.62±0.31) at 12 months after planting. The NHB in CP+PM+SW+MS (12.10±0.04) and CP+SW+MS (11.97±0.04) were similar but significantly higher than CP+PM (10.93±0.04) and control (6.43±0.04). The BWH at 18 months from CP+PM+SW+MS (10.87±0.56) and CP+SW+MS (10.68±0.56) were similar but significantly higher than CP+PM (10.28±0.56) and control (8.96±0.56).

Composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%) and cassava peel, Siam weed and Mexican sunflower (70%+15%+15%) gave considerable amount of potassium determined and high yield in banana production, which could be recommended for use by farmers.

Keyword: Incubation, Cassava peel, Compost, Nutrient release pattern, Fertilizer use efficiency

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CHAPTER ONE

INTRODUCTION

Soils in the tropical environment encounter fast deterioration due to thin plough layer and the type of farming practices adopted by the farmers. Climate change is unpredictable, especially when it comes to rainfall is among the contributing factors of damage to the soil. When natural or manmade activities destroy the intrinsic physical, chemical, and/or biological properties of soil, it affects or completely eliminates crucial ecosystem services. Erosion, a drop in organic matter, biodiversity loss, compaction, sealing, point-source and diverse contamination, pollution, and salinization are the key factors that contribute to soil degradation and, as a result, pose the greatest challenges to the ecological functions of the soil (Montanarella, 2007). This has restricted crop cultivation in Africa to specific times of the year. In order to create alternative soil fertility management techniques and raise public awareness of the issue, soil scientists have selected soil fertility management as a starting point for re-establishing lucrative banana stands.

The planting of cover crops, green manuring, organic manuring, erosion avoidance, and maintaining soil water balance (field capacity), as well as other soil management techniques, help maintain and improve soil fertility over time while assuring optimal crop output. This is one of the many crucial factors for the long-term success of tropical agriculture. In order to restore soil nutrients, human or animal dung, composting, green manuring, agricultural residue management, and inorganic fertilizers can all be used. The organic agricultural wastes from diverse farm sites could be used as manure, either alone or in combination, to boost banana and other crop yields. The farmers can achieve maintenance and improvement of soil fertility at a low cost and affordable within their means. The soils of the tropical region should be treated with caution to avoid problems such as loss of soil organic matter, high soil infiltration capacity, leaching, and soil erosion by rain. These factors, alone or in combination, can damage the soil, resulting in less farming activity and lower yields. Farmers understand the value of mulching, but struggle to discern between the advantages of various types of mulch and their application rates. Mulching is preferred by farmers because for the shallow-rooted banana crop, it keeps the soil fertile and preserves soil moisture while reducing weed development. Banana leaves, plant bits pruned by harvest tools and left over after harvest are all scattered on the plantation site for gradual disintegration for plants use. Outside the farmers' fields are other organic resources he can utilize, he can get some organic materials from fallow areas to augment whatever he has. Available weeds on his farm can also be utilized as mulch for banana production.

Weeds are plants that grow freely (not deliberately planted), severally (annually or perennially) in our environment on farmers' field which constitute agronomic and economic nuisance to growing crops. The two commonest examples of such plants are Siam weed (*Chromolaena odorata*) (L.) R.M. King & H. Robinson) and Mexican sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray). Mexican sunflower and Siam weed grow severally and annually in farmers' proximity which could be put to agronomic uses like utilizing them as mulch for banana production instead of watching them grow unused. *Chromolaena* is the main fallow vegetation in southwest Nigeria, where it thrives lavishly and renews the soils. It has the capacity to serve as a source of nutrients (Akanbi and Ojeniyi, 2007). Poultry manure is the waste from poultry birds whose benefits are not fully exploited by farmers. Adeoye *et al*. (1994) reported that poultry wastes cause environmental degradation in Nigeria due to emission of disagreeable odors and encouraging the multiplication of flies and rodents. Typically, poultry manure is dumped on farms in its raw state or stacked and burned. Cassava peel is waste generated across Nigeria from "garri" processing units on daily basis. The only form of use is as feed to pig, goat and sheep. Cassava peels from processing units constitute environmental nuisance because of its underutilization as well as hydrogen cyanide (HCN) content. Aro *et al*. (2010) noted that in Nigeria, cassava wastes are typically burned or allowed to rot away to make room for the encroachment of new waste mounds. The piles give off a potent unpleasant odor and carbon dioxide emissions.

The banana plant originated from South East Asia. Banana is a soft, sweet dessert *Musa* cultivar which is largely produced for its fruits and fiber (Frison and Sharrock, 1998). The fruit is obtained from herbaceous plant that grows and replaces itself annually by succeeding suckers (ratoons) growing before the mother plant is harvested. Banana is a popular fruit and food crop throughout the tropics and subtropics. The banana (family Musaceae) is a seedless, elongated, curved fruit with a sweet creamy flesh and a smooth yellow skin that grows in bunches. According to Morton (1987), *Musa acuminata* Colla is a product of the cross (Musa cavendish Lamb. ex Paxt., Musa chinensis Sweet, Musa nana Auth. Lour., Musa zebrina Van Houtee ex Planch., while Musa sapientum L. was a product of the cross M. acuminata X Musa balbisiana Colla. Musa balbisiana Colla is a plant native to southern Asia and the East Indies, whose seedy fruit is renowned for its disease resistance and is used as a "parent" in the breeding of palatable bananas. (INIBAP, 2001).

Banana is a fruit crop that has capacity to improve the nutritional diet of man whenever it is taken. Bananas are in high demand all year due to their delicious taste and nutritional value. According to Gowens (1995), it is possible to pick fruit every day of the year by banana producers in the tropics. The lack of seasonality in production is a benefit since it ensures a steady supply of carbohydrates to meet nutritional requirements as well as a consistent source of income (Gowens, 1995). During the various phases of ripening and growth, fruits are consumed and processed in a variety of ways, resulting in goods with longer shelf lives, such as flour, chips and beverages. Bananas are produced in India and other Asian nations for their leaves (for plates or fuel) or for the fiber derived from the pseudostem (for ropes and fishing nets). In Southeast Asia, the flowers and terminal buds are cooked or uncooked, while the pseudostem is primarily consumed in times of famine or fed to pigs. Banana production is year-round, providing a food 'bridge' between grain harvests when food is in short supply. Bananas are perennial, which means they can be produced on the same area of land for up to 50 years (Mateete, 1999).

Available data indicate that between 2000 and 2017, global production of bananas grew at a compound annual rate of 3.5 % given the world production in 2017 estimated at 114 million tonnes (t) annually (FAO, 2017). Banana is harvested on about five million hectares (ha) around the world, yielding over 107 million t in 2013, with 18 million t coming from 881,000 ha in Southeast Asia (FAOSTAT, 2017). The global average yield is 21 t /ha. With 32 million metric t, India is the world's largest producer. Bananas are widely grown in all tropical places since they are a tropical plant that thrive in hot weather. Other important world producers are China, the Phillipines, Ecuador, Brazil, Indonesia and Tanzania. Ecuador, the Philippines, Costa Rica, and Colombia are the top exporters of the fruit while the United States, Belgium, and the Russian Federation are the top importers (André and Jim, 2014). FAO (2017), reported that Africa exported 3.9 % of all bananas shipped around the world. Cameroon exports, after Côte d'Ivoire, as the second-largest African exporter saw a 6.5 % increase to 283,000 t. Only around 20 % of the over 80 million t of bananas produced around the world is exported. The rest is consumed in the area.

In Nigeria, banana is produced in the following states: Ogun, Osun, Ondo, Lagos, Ekiti and Oyo, parts of South Eastern and South Southern states that produce banana are Edo, Delta, Anambra, Enugu, Imo, Ebonyi, Rivers, Bayelsa, Akwa Ibom and Cross Rivers at the borders of Cameroun as stimulus for production. The crop is also grown partly and scantily at the riversides in the states of Norhern Nigeria like Niger and Kaduna. Although Nigeria is a large producer of banana but not having a comparative advantage as regards the crop. All banana produced in Nigeria are for local consumption, leaving nothing for export. Akinyemi *et al*. (2010) reported that at varying stages of ripening, The fruits of the majority of Musa species are consumed raw or converted into different items. According to FAO (2014), losses following harvest along the banana value chain are estimated at over 60 % of production.

The Cavendish banana is a tall, golden yellow type that is widely available in supermarkets. They are bright in color, uniform in size, have thick skin, and are simple to peel. Until the Panama disease drove it off in the 1950s, the Gros Michel (literally 'Big Mike') was the most prevalent grocery type. The Cavendish was unaffected by the disease and went on to become the most popular export banana as it became more popular for mass production. Cavendish bananas are a sub-group of the triploid AAA cultivars of *Musa acuminata*, hence the botanical name *Musa cavendish*. It is a different species from the others. It is short, not prone to wind damage being only 1.5-2.5 m tall. The fruits stand out from the stem and are smaller but sweeter than those of other species.

Depletion of soil nutrients is thought to be the cause of the recent fall in banana productivity, among other issues, which could be a result of continued use without replacement over time. There is need to produce Banana with available organic materials in the vicinity of farmer’s growing area without the use of chemicals in form of fertilizer, herbicide and insecticide. This is called organic production. The recent global awareness of ozone layer depletion by several and uncontrolled use of synthetic materials is a serious issue that needs quick attention especially in Nigeria and other developing countries. To this end, organic fertilizer or cassava based composts should be embraced for banana production and other crop productions for sustainable agriculture in Nigeria. This means that production should be geared towards the use of available local organic / agricultural wastes which are cost effective with impressive results for farmers. These organic wastes have been found to be environmentally friendly, available at all times and also at a cheap cost compared to the synthetic fertilizers. Efforts should therefore be made to increase banana productivity in Nigeria at a reasonably cost-effective way with composts and use of mulching materials.

This is achievable going by climatic endowment of Nigeria and the vast area of land available for crop production. Apart from satisfying local demand of banana, having some for export will not only boost the image of Nigeria (as an export nation) but also add to her foreign exchange earnings. To this end, Nigeria government is taking steps to expand banana production to meet both domestic demand and export. One of the key steps was the establishment of the National Initiative on Tropical Fruits Production, with a target of achieving 10 % of world production output of banana and plantain (FAO, 2014). As a result, the purpose of this study was to evaluate the effectiveness of Mexican sunflower and Siam weed as mulching materials in the production of bananas as well as the use of different cassava compost-mix to grow banana in Ibadan, Oyo State - Southwestern Nigeria.

The objectives of this study were to:

i. investigate the response of two cultivars of banana (Williams – Large and Medium) to sole and combination of Siam weed /Mexican sunflower mulching,
ii. study nutrient release pattern of cassava peel based composts mix during incubation with washed river sands over time
iii determine the effects of various composts on banana growth and yield.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil fertility

Soil fertility is a term used to describe a soil's capacity to sustain plant growth and development, which is governed by the soil's physical, chemical, and biological qualities (Nandwa, 2003). It refers to the soil's capacity to provide crops with the nutrients they require to grow. Water penetration and drainage, soil structure, active soil life, exploitable soil depth, mineral content, and soil acidity (pH) are all factors to consider; accessible nutrient content, parent soil character, and ground water are all elements that contribute to soil fertility. Many methods for assessing soil fertility have been developed to test growth, development, toxicity, and nutritional deficits on plant performance, studies conducted including field trials and pot cultures.

Fertility of a soil is also measured by chemical and biological analyses: Nitrogen nitrate, pH, and ammonium; Soil microorganisms include nitrifying bacteria, nitrogen-fixing bacteria, and mycorrhizae that are free-living, symbiotic nitrogen-fixing bacteria. Manures, composts, fertilizers, water usage, irrigation systems, and other materials are evaluated using field tests according to Ognyan (2016). Site selection, layout, testing phases, and qualitative and quantitative analysis are all important components of such testing. Plant growth, biomass increase, time for fruit to ripen or commercialization, fruit production, and profitability are all indicators of success.

2.2 Quality of the soil and organic fertilizer use

The capability of a soil to preserve its structure, productivity and biodiversity, as well as nutrition cycling and assistance for plants, is a measure of its quality (Toth *et al.*, 2007). There are several possibilities available to determine soil quality, however it may be more practical to have a smaller collection of indicators, while still presenting the most important details. Obatolu (1995) reported the usage of organically based fertilizer materials is expected to be a benefit compared to mineral fertilizer, which is becoming extremely expensive and difficult to obtain for the average Nigerian and indeed most third world farmers. With the elimination of inorganic fertilizer subsidies and the epileptic functioning of the inorganic fertilizer companies in Nigeria, the likelihood of supplying future fertilizer needs is relatively slim. It is interesting to note that several locals in north-central Nigeria discourage the use of chemical fertilizers because they feel it threatens the health of the soil, in accordance with their local customs. (Kolawole, 2006). Ipadeola and Adeoye (2014) reported that degradation of the environment is put at check while conservation agriculture is enhanced with the use of organic fertilizers.

Techniques for cultivating bananas include replanting and rotating crops, controlling weeds, organic fertilizing and combining intercropping. to increase cash flow. In most farmers' fields, there are plenty of stems, dry leaves, grass, weeds, and other human leftover wastes that are organic wastes. These organic wastes include significant amounts of organic carbon and plant nutrients. When organic waste is composted and applied, it is safer and more helpful than when it is applied directly. Since more than 50 years ago, several research on the use of manure to increase the productivity of arable crops in Nigeria have been carried out, beginning with Harthley and Greenwood's pioneering work of 1933.

The focus of early investigations was mainly concerned with the nutrients supplying power of Farm Yard Manure (FYM) on cotton, sorghum and millet. In the study, comparison was made of the soils treated with 4.5 t FYM /ha and NPK fertilizers applied together at the rates of 29.5 kg N/ha applied as ($NaNO_3$), 13 kg P_2O_5 (as single super phosphate) and 50 kg K_2O/ ha (as KCl). These studies showed that the yields of crops produced with FYM and NPK were equivalent, and when they were combined, the yields with NPK were higher than with FYM alone. Akinyemi *et al*. (2004) recommended 20 t/ha organic fertilizer in plantain cocoyam intercrop and 450 kg /ha NPK 15-15-15. Banana should be manured at a rate of 9.8 t/ ha, in line with (Memon and Leghari, 1996) but Wiebel *et al*. (1994) noted that 12 ton/ ha FYM proved to be a popular management technique.

Adeoye *et al*. (2005) noted that because of the swift decline in soil fertility in tropical areas and the prohibitive cost of chemical fertilizers, manures from unapproved solid waste dump appeal to poor peasant farmers as a fertilizer or soil conditioner alternative. Sridhar *et al*. (2001) observed that many tropical, underdeveloped countries, such as Nigeria, use compost or manure as an organic source of nutrients in agriculture. The low nitrogen (N) content of such materials is one of its disadvantages. Alternative materials were explored due to a shortage of FYM in damp environments when a survey of 45 different waste materials was carried out for N, P, K, Ca, Mg, Zn, Cu, Fe and Mn contents (Agboola *et al.*, 1981). Sawdust seems to offer some prospect as evident from the studies of Olayinka (1982) who showed that sawdust amended with inorganic fertilizers (NH_4OH and H_3PO_4) gave better maize yield.

According to Ognyan (2016) to ensure continual soil microbial activities and to keep groundwater, rivers from becoming contaminated, to reduce human health risks connected with pesticide use, we must restrict CO_2 and N_2O emissions that contribute to temperature rise or warming of the planet, and in order to maintain the soil's quality for future generations, irrigated land must be waterlogged and added with basic salts, fertilizer use should be accompanied by organic material recycling. In tropical agriculture, it is critical that plant nutrients are determined from soil organic matter and organic manures. The importance of organic matter in the soil for sustaining soil fertility, water holding capacity, cation exchange capacity, pH boosting, and preventing soil surface hardening cannot be overemphasized. Cover crops, animal manure, and better fallows are examples of various initiatives to promote agriculture with less external inputs (Kostov *et al.*, 2002). The soils in Nigeria are becoming less productive. Lands have been exploited extensively for a variety of purposes, which has caused land degradation and altered the natural biological conservation balances in the environment.

2.3 Organic Agriculture in the Tropics

Africa’s soils, which are essential for agricultural productions are also divergent in nature: they come in a variety of textures, types, classifications and characteristics, including desert, poorly developed sand Luvisols and Acrisols, Nitrosols and Acrisols, and Ferrasols and Lateritic soils. The low cation exchange capacity (CEC) of African soils is well known (Kolawole, 2013), it invariably impedes the uptake of essential plant nutrients by crops even in scenarios where inorganic fertilizers have been applied. If organic manures and crop wastes are employed to enhance soil quality, the capacity for nutrient release can be sustained (Scoones and Toulmin, 1999); noted organic fertilizer is an appropriate medium that encourages the development and activities of soil microbes as well as the enhancement of soil structure.

Just as Castillo (2000) noted, applying easily soluble Phosphorous (P) fertilizer is a futile effort in a P-fixing soil environment, is a typical occurrence in the tropics and subtropics. In other words, Chemical fertilizers aren't the only way to improve Africa's soils; they need to be supplemented as well (wherever possible) with the use of organic manures. African agriculture naturally uses little to no chemicals in the production process (Walaga, 2004). A " a single-cause reason-effect relationship" type of solution (such as using inorganic fertilizers alone to increase soil fertility) gives way to a systemic approach (such as in a situation of mixing) that seeks to address issues holistically rather than offering a "one-size-fits-all" prescription (Joergensen, 2002; Kolawole, 2013). In tropical Africa, this is the region's first foundation for organic farming. The second justification for promoting organic farming in the tropics is that the majority of food producers, small-scale

African farmers, are poor and hence unable to employ high external inputs (HEIs), which are highly expensive to get. Thirdly, even in cases when these technologies are easily accessible (such as with fertilizers), rent-seeking politicians and their allies rig the supply and distribution networks in favor of the wealthy who already have the resources to operate in the agricultural sector (Kolawole, 2012). Fourth, a paradigm shift is necessary in light of the relatively recent climate change predictions and the associated environmental issues. It is well known that increased contemporary agriculture has a negative impact on global warming in terms of greenhouse gas (GHG) emissions and pollution. Environmental and human health are impacted by this. Zoonotic illnesses, some of which are predominantly brought on by climate change, thrive in an excessively warm, humid, and waterlogged/flooded environment, where they would typically not survive.

According to the Guidelines of Organically Food Produce of the Codex (2007), increasing the system's biological variety is the goal of an organic agricultural system. It is important to maintain the soil's long-term fertility. However, the usage of nonrenewable resources is reduced by returning nutrients to the soil through the recycling of plant and animal waste. In localized agricultural systems, rely on renewable resources. Encourage the use of healthy soil, water, and air, as well as the reduction of any pollution generated by agricultural activities. Promote the use of precise processing techniques for agricultural products to guarantee the ongoing preservation of the product's essential properties and organic integrity. By completing a conversion phase, which is decided by site-specific elements like the history of the land and the crops and cattle that will be produced, you can establish yourself on any current farm.

According to International Federation of Organic Agriculture Movement, IFOAM (2003), the fundamentals of organic farming are as follows: Organic agriculture's goal is to maintain and whether through cultivation, processing, distribution, or consumption, improve the condition of ecosystems and species from the soil's smallest organisms to humans. As a result, it should refrain from using fertilizers, pesticides, animal medications, and food additives that could endanger people's health. Ecology principle: Organic farming should be built on living ecological processes and cycles that should be manipulated, replicated, and supported in order to ensure their long-term viability. Local factors, environment, culture, and size must all be considered when practicing organic management. Reusing, recycling, and managing materials and energy effectively can reduce inputs, enhance environmental quality and resource conservation.

Fairness Principle: This idea emphasizes how crucial it is to manage human relationships in organic agriculture so that everyone—farmers, staff members, processors, distributors, merchants, and customers—benefits. Additionally, it states that animals should have access to opportunities and living arrangements that are consistent with their physiology, typical behavior, and general well-being. It is important to manage natural resources properly on a social and environmental level and to protect them for upcoming generations. To be fair, manufacturing, distribution, and trade systems must be open, inclusive, and cost-effective.

Principle of Care: This principle highlights that in organic agriculture, the most significant aspects in management, development, and technology choices are prudence and responsibility.

When studying Nigerian soils, Esu (2005) found that organic material serves as a binding agent for soil particles to agglomerate, encouraging good soil structure and efficient drainage, although Pagliai *et al*. (2004) emphasized that applying organic fertilizer can improve soil structure by retaining continuous transmission pores across the profile and conserving the soil surface. When applied to the soil, soil organic matter and holding onto a sizable amount of soil water, poultry manure with a high percentage of organic carbon content improves soil water content. (Mohamed *et al*,. 2010). In heavy soils, the degree of aggregation, total porosity, and hydraulic conductivity are positively impacted by the amount of organic matter present (Anikwe 2000).

2.4. Organic Farming

Organic farming necessitates scientific validation to ensure that it is healthful, safe, and environmentally friendly. Meena *et al.* (2013) noted the practice of organic farming, relies, as much as feasible, on crop rotation, crop residues, animal manures, off-farm organic waste, mineral grade rock additions, and biological mechanisms of nutrient mobilization and plant protection rather than completely forgoing the use of artificial inputs (such as fertilizers, pesticides, hormones, feed additives, etc.). Currently, 120 countries commercially practice organic agriculture, this includes 62 million acres of wild lands that have been certified for the collection of 31 million ha of certified croplands and pastures, as well as an organic harvest of bamboo shoots, wild berries, mushrooms, and nuts (0.7 percent of the world's agricultural lands). (Willer and Youssefi, 2007).

According to Meena *et al*. (2013), In Africa, the total area of 890 504 hectares of land are certified as organic (or 0.12% of all agricultural areas), with the bulk of them being permanent crops including cotton, herbs/spices, tropical fruits, nuts, coffee, and cocoa etc. Uganda has the most organic farmers in the world, out of the 124 805 farmers employed in the sector across 24 nations. The largest countries that practice organic farming are Sudan (200 000 ha and 650 farms), Kenya (182 586 ha and 15 815 farms), Uganda (182 000 ha and 45 000 farms), Tunisia (143 099 ha and 515 farms), Tanzania (38 875 ha and 43 791 farms), and Zambia. (2 884 ha and 9 248 farms). Most organically produced goods are intended for export, mostly to the European Union.

Yet, it must evaluate workable solutions in light of actual experience, gather traditional and indigenous knowledge, and reduce serious risks by embracing appropriate technology and avoiding riskier ones like genetic engineering. Organic nutrients can be found in plant leftovers, leguminous cover crops, mulches, green manure, and household trash. By strategically combining these organic resources with chemical fertilizers, immediate nutritional reserves can be assured. Replenishing soil organic carbon lost through degradation by bringing organic matter back into the soil (plant and animal residue recycling, farmyard and green manuring, composting, cover crop rotation), minimization of soil surface disturbance (residue mulch, conservation tillage), and lowering soil temperature and water evaporation via soil surface mulching have all been researched recently (Franzluebbers *et al.*, 1998).

2.4.1. Advantages of Organic Farming

Nutritional, wholesome food that tastes good: A food's nutritional value is largely determined by the number of vitamins and minerals it contains. As a result, food produced utilizing organic methods has a much higher mineral content than food produced using modern conventional methods. Customers benefit greatly from the absence of toxic chemicals like pesticides, fungicides, and herbicides in organic food. Standard vegetables are consistently seen to contain lower levels of vitamin C and higher levels of nitrate (Woese *et al.*, 1997).

According to several studies, organic dairy contains 10–60% more beneficial fatty acids (such CLAs and omega-3 fatty acids) than conventional dairy (Butler *et al.*, 2008). Vitamin C levels in crops can increase by 5 to 90%, and organic crops also contain 10 to 50% more secondary metabolites. Additionally, there are fewer pesticide and antibiotic residues. (Huber and van de Vijver, 2009). According to Heaton (2002), organic food includes 10–50% more phytonutrients, as well as higher levels of minerals and dry matter. On extracts of organic strawberries, cancer cell proliferation was found to be reduced (Olsson *et al.*, 2006). The Parsifal study found that 14 000 kids in five EU countries who ate organic and biodynamic food had 30 percent less eczema and allergy symptoms, as well as lower body weight (Alfven *et al.,* 2006).

According to additional research, secondary metabolite concentrations are what distinguish organic from conventional crops in a systematic manner. (Brandt & Mølgaard, 2001). Compared to conventionally cultivated food, organic food has a better flavor. Fruits and vegetables are either sweet or bitter depending on the quality of the nourishment they received as a plant. By putting a fruit or vegetable's juice through a brix analysis, which measures the specific gravity of the liquid, this characteristic can be empirically determined (density). Prior to export, fruit and vegetable quality is frequently assessed using the brix score. Plants grown organically receive natural nutrition, which improves the cellular structure's structural and metabolic integrity above that of plants grown conventionally. So, organically agricultural products have a longer shelf life and are less susceptible to mold and decay than industrial products.

Reduce growing cost: Reduced water consumption, lower fertilizer and energy costs, and increased topsoil retention are characteristics of the economics of organic farming, which increases profits. Also, the rising demand for organic food makes it a lucrative choice for farmers to practice organic farming.

Improves soil nourishment: Organic farming is a good method for managing soil. Even degraded, salinized soil can consume micronutrients thanks to crop rotation, intercropping techniques, and extensive use of green manure. Since pesticides are not used in organic farming, beneficial soil-improving bacteria are not eliminated. In terms of organic matter, content, and microbial activity, biodynamic farms had improved soil quality. Additionally, they possessed thicker topsoil, more earthworms, better soil structure, lower bulk density, and easier penetrability (Reganold *et al.,* 1993).

More efficient use of energy: Compared to conventional ways, growing organic rice required four times less energy (Mendoza, 2002). The energy needs of production processes are lowered by 25% to 50% when comparing conventional chemical-based farming to organic farming (Niggli *et al.*, 2009).

Carbon capture and storage: German organic farms sequester 402 kg of carbon per hectare annually, as opposed to the 202 kg lost by conventional farms (Clark *et al.*, 1999; Küstermann *et al.*, 2008; Niggli *et al.*, 2009).

less toxicity in the water: Over a five-year period, conventional farms leak 60 percent more nitrate into groundwater (Drinkwater *et al.*, 1998).

Environmentally friendly methods: Neem, compost tea, and spinosad are examples of green pesticides that are non-toxic and safe for the environment. By helping to quickly identify and remove diseased and dying plants, these pesticides boost crop defense mechanisms. Organic farms are better able to withstand climate change and unpredictable weather as a result of their increased diversification (Niggli et al., 2008). At a pace of 10 million hectares per year, overgrazing, wind, and water erosion are all prevented by organic farming (Pimentel *et al*., 1995).

Workforce productivity can be found in organic farming: The primary industry of employment in rural areas is agriculture, and for the poor, paid labor is a key source of income. Furthermore, because organic agriculture requires a lot of labor, fair salaries and non-exploitational working conditions are among the benefits that boost the returns on labor, as well as employment opportunities. Rural economies are subsequently revitalized and made easier to integrate into the national economy by new sources of income, particularly after market opportunities are taken advantage of.

2.4.2. Disadvantages of Organic Farming

Lower productivity: A conventional or industrial farm can yield more than an organic farm, which cannot. In comparison to conventional farming practices, organic farming yields are low even in underdeveloped countries, according to a survey and analysis from 2008 by the UN Environmental Program. Yet there is some debate about this because an industrialized farm's production and soil quality gradually deteriorate with time.

Requires skill: Given that there are no easy cures, like pesticides or artificial fertilizers, an organic farmer must have a deeper understanding of his crop and thorough monitoring of it. It can be difficult to fulfill all the demanding conditions and gain the expertise required to engage in organic farming.

Time-consuming: It takes a lot of time and effort to carry out the complex procedures and processes a farm must have in order to be referred to as an organic farm. The farmer may lose certification and won't be able to reclaim it for up to three years if any of these standards are not met. Also, it can take additional time. Compost, organic fertilizers, and mulch are all ways that organic farming promotes soil fertility. Slow-release organic fertilizers are typical. Similar to the use of horticultural oils, insecticidal soaps, and botanicals to control pests, organic fertilizers may require multiple applications to achieve the desired outcomes.

It may require more labor: it may be more labor-intensive. As biological, cultural, and mechanical solutions to production issues are taken into account in organic farming. It emphasizes the health of the plants and the soil by providing enough aeration, drainage, fertility, structure, and watering. There is therefore more grueling above and below ground work involved.

The use of organic farming practices is still less common and well-established than conventional cultivation. Hence, organic pest control using plants like pyrethrin may be more expensive than conventional pest control using artificial, commercial, synthetic chemical pesticides that have a longer history, are more prevalent, and have a larger range of uses.

Due to the stringent regulations organic farming involves much more inputs and paperwork than conventional farming because of the requirements that must be satisfied in order to maintain the organic label. If something goes wrong, the farm's organic certification is immediately revoked.

2.5 The Nigerian Environment is Heterogeneous

The continent of Africa with a total land size of 30.1 million km^2, having natural water resources covering roughly 2.3 million km^2 (FAO, 1978). In terms of agricultural resources, the continent is diversified. According to Nandwa (2003), over 27 % of Africa's entire landmass is deemed potentially suitable for agricultural production (about 874 million ha). Due to insufficient infrastructure, diseases (human, cattle, and plant), and fluctuating rainfall, most of the humid central region are not exploited for agriculture. This is by extension the exact situation in Nigeria, from the northern part to southern part, to the eastern and western part, the land are not homogeneous and as so the environment. This limits the cultivation of certain crops to particular region of the country.

2.6. Organic Mulching

According to Ranjan *et al.* (2017), mulch is a natural or artificial coating of plant waste or additional items positioned on the top of the soil. Mulching today describes the addition of any number of substances to the soil's top layer near a growing plant's stem in order to enhance root conditions. Mulching has a number of advantages for soil conditions. The soil is safeguarded by mulch against intense heat and gives a crucial method for water conservation, not only via increasing the soil's ability to absorb rain, but also by evaporation (Muhammad *et al.*, 2016). Moisture conservation, temperature regulation, some of the key purposes of mulching in agriculture are surface compaction prevention, runoff and erosion reduction, soil structure development, and weed control. Improved soil structure, increased water holding capacity, moisture conservation, and better soil drainage properties are all examples of soil improvement. Organic mulches reduce soil erosion and control soil temperature, provide plants with nutrients as it slowly composts, supplying plants with year-round nutrition and defending the landscape from infections and pests, improving healthy organisms and eliminating contaminants. Mulch has been demonstrated to be helpful in increasing the amount of nutrients in the soil with Phosphorus P, Magnesium Mg, Organic C, and, most critically, Potassium K in banana plantations (McIntyre *et al.,* 2000).

One farm management method for improving crop weed management and water efficiency areas is mulching (Unger and Jones, 1981). Mulch is created from a variety of components, including grass, wood, sand, oil layer, plastic film, rice husk, wheat straw, and so forth (Khurshid *et al.,* 2006). Mulch in crop production is a conservation measure that has aided farmers in their diverse methods. Mulch helps to improve the soil environment by lowering soil temperature, increasing soil porosity and water penetration rate, reducing runoff and erosion, and suppressing weed growth during heavy rains (Bhatt and Kheral, 2006). Organic mulches provide extra advantages after decomposition, such as boosting plant nutrients, raising soil quality, and boosting biological activity, as well as improving soil organic matter content and Cation Exchange Capacity (CEC) (Tian *et al.,* 1994). Both living mulch and organic mulch have an important bearing on fertility of the soil as well as the crop that is produced.

According to Szwedo and Maszczyk (2000) the ability of mulches to attract or repel mammalian pests vary from the nature of mulching materials and the time of use of the mulch. Some materials that has thorns, odors, or texture, may naturally deter herbivorous mammals, but others may attract pests, particularly rats, who might find shelter in dense ground covers or sheet type mulches. Sunderland and Samu (2000) reported any mulch that enhances the overall health of the soil ecosystem would almost certainly increase the variety of healthy bacteria and insects in the environment. As a result, for soil fertility enhancement and sustainability, a better use of weeds, either alone or in combination with other resources, is achievable. By suffocating existing weeds and preventing those that need light for germination from receiving it, mulch helps a plantation have fewer weeds.

It also promotes water retention by allowing it to seep deeper into the soil. Furthermore, when it decomposes, it restores minerals to the soil, enhancing its fertility (Wilberforce *et al.*, 2001). Residue quality, as defined by Swift (1985), is the inherent nature of a resource or the elements that determine the rate at which it decomposes. Low-quality materials have properties that prevent breakdown, for instance, high polyphenol or lignin content or low N content (high C:N ratio), whereas good-quality residues have a low lignin concentration (low C:N ratio). Mark (2012) observed that weeds are suppressed by organic mulches in a variety of ways.

First, through light interference, reduction in soil temperature, and considerably decreasing temperature swings between day and night, they limit seed germination stimulus. As a result, and in comparison to bare soil, weed seeds develop less frequently beneath cover. The second benefit of mulch is that it physically stops weeds from sprouting; if the mulching material is thick enough, light is blocked from reaching the confined seedlings, which eventually die. Thirdly, natural chemicals determined by some mulching materials, weed seedling growth will be stopped for several weeks by forages such freshly cut sorghum-Sudan grass and grain straw following spraying, a process known as allelopathy. Last but not least, organic mulch can boost crop development and weed-control efficiency by retaining soil moisture and lowering soil temperature. Mineral deficiency can be corrected by the addition of plant and animal manures into the soil. The secret behind getting a healthy banana plantation is for the soil to have plenty of organic matter at the time of planting and thereafter (Ngeze *et al*, 2004). According to FAO (2015), sources of mulch materials could be cover crops or weeds, residues from agricultural crops Grass, Tree prunings, hedge cuttings, or agricultural or forestry waste. Ranjan *et al.* (2017) reported additionally seen to enhance soil qualities are organic mulches. It enhances the biological, chemical, and physical qualities of the soil. These mulches enrich the organic matter in the soil and gently break down, keeping the soil flexible.

These organic compounds feed the beneficial earthworms and bacteria in the soil. Organic mulches also help to boost the quantity of organic carbon in the soil. The soil becomes increasingly fragile as organic carbon levels rise. It enables better root penetration, root growth, and nutrient absorption from the greater depths of soil. It improves crop root growth, boosts water infiltration, and increases the soil's water retention capacity. Most of the soil's advantageous microflora are drawn to organic mulches because they operate on degradable waste and facilitate the release of plant nutrients.

2.7 Mulch materials

2.7.1 Siam weed (*Chromolaena odorata* (L.) R. M. King & H. Rob)

The Asteraceae family member referred to as "Siam weed" (Chromolaena odorata) (L.) R.M. King & H. Robinson is an invasive bushy shrub that has spread throughout many tropical and subtropical areas of the world. It originates from South and Central America. It came from Southern Mexico and was made available in several ecological zones of tropical lands (Owolabi *et al*,. 2010). In 1940, Siam weed was initially discovered in Africa but has now become a common weed in Nigeria, Ghana, Cameroon, Zaire, and South Africa. In the tropics of Africa and Asia, it is a significant pest of crops like coconuts, rubber, tobacco, and sugar cane. Siam weed is a perennial shrub that belongs to the Asteraceae family. The weed has common names in English as archangel, bitterbush, Christmas bush etc. Herbaceous to woody perennial. C. Odorata has a bushy growth pattern and thrives in nearly pristine stands. It develops a very dense thicket that is about 2 meters high. In tropical regions, It is a plant that has spread over several ecological zones.

The scrambling perennial shrub C. *odorata* has straight, pithy, brittle stems that branch easily, bears three-veined, ovate-triangular leaves that are arranged oppositely, and has a shallow, fibrous root structure (Henderson, 2001). It produces an abundant amount of seeds and grows up to 20 mm each day (Owolabi *et al*., 2010). It has turned into an agricultural weed in the tropics of Africa and Asia. While it may thrive in most types of soil, it likes well-drained soils with full sun. In the tropics of Africa and Asia, it has developed into an agricultural weed. Despite being able to thrive in several types of soil, it prefers well-drained soils with full sun. Siam weed is an aggressive, quickly growing plant that prefers disturbed places, particularly those that are well-lit, such as clearings, pastures, roadside ditches, river banks, and plantations. Siam weed is one of the environmental weeds that are on the watch list because it threatens biodiversity and harms the environment in various ways.

In some agricultural areas in Southeast Asia, Siam weed has taken over meadows and crops, forcing them to close down. In the Phillipines, animals are poisoned by Siam weed, which kills roughly 3,000 cattle per year. Animals that ate the uncooked leaves died owing to the high nitrate level (Sajise *et al.*, 1974). The most likely cause of death was the conversion of nitrate to nitrite, either in the feed or in the animals' digestive tracts. The blood's haemoglobin then undergoes a reaction with the nitrite to become methaemoglobin, which is incapable of delivering oxygen and may result in tissue anoxia, which could kill the animals (Sajise *et al.*, 1974). When consumed by pregnant calves, the toxin, which is also thought to be a fish poison, induces abortions in those animals. Asthma and skin diseases are only two examples of the health problems that people have. A perennial herbaceous plant called siam weed grows in 1.5–2.0 m-high thickets of tangles and has a distinctive fragrant smell (Phan *et al.*, 2001).

The plant is known by the name Obuinenawa, Obilidiages, Obiara ohua ewa uta, abiralah, abilidiegan by the Igbos, ebe Awolowo (Edo) and " Awolowo or Ewe Akintola" by the Yorubas (figure 2.1). It originated in southern Mexico and spread to Argentina and the Caribbean, but it has now spread to a number of tropical habitats (Moses *et al.*, 2010). In Tropical Africa, Siam weed has developed a reputation for treating ailments like malaria, dysentery, toothaches, diarrhea, diabetes, skin issues, fever, and wound dressing (Phan *et al.*, 2001). Bamisaye *et al.* (2014) reported Siam weed contains phytochemicals such as flavonoids, phenolics, saponins, steroids, and tannins, which validates its antiviral, antibacterial, anti-parasitic, and anti-inflammatory activities.

Many tropical countries have long employed fresh leaves or a decoction of C. *odorata* to treat leech bites, soft tissue wounds, burn wounds, skin infections, and

Figure 2.1 Siam weed (*Chromolaena odorata* (L.) R. M. King & H. Rob)

liver illnesses (Alisi *et al.*, 2011). Obadoni and Ochuko, (2002) pointed out that the reduction of whole blood coagulation time and clotting time, two crucial indicators of haemostatic activity, caused by the C. odorata crude extracts prevented fresh wounds from bleeding, and Anyasor *et. al.* (2011) confirmed this.

When climbing up vegetation, Siam weed is a perennial upright shrub is capable of heights of 5 meters and produce dense spreading thickets, as well as sprawling and scrambling plants that can reach a height of 20 meters. It develops a huge number of stems from a long-lived root stock, at the base, the stems are slender and woody. Side branches are usually found in pairs. The Siam weed produces a large number of seeds that are distributed by the wind. Seeds can be found in a variety of places, encompassing areas with dry seasons, C. *Odorata* can be a fire hazard (Englberger, 2009). During the rainy season, seeds germinate, and in seedlings that germinate early in the rainy season grow swiftly. It has been recommended as the best plant for mitigating desert encroachment because of its ability to improve soil and propensity to spread to new areas, especially in the Sudano-Sahelian ecological zones of Africa. Another study carried out by Aro *et al*. (2009) stated that the application of Siam weed has a high potential for egg yolk colorant for laying hens, and that this may be a turning point from the eradication campaign to its delicate cultivation, clothing, animal fur, and equipment.

2.7.2 Mexican Sunflower- (*Tithonia diversifolia (*Hemsl.) A. Gray)

Mexican sunflower refers to a variety of sunflowers traced to Mexico and Central America as home of origin. Mexico and Central America are home to a total of roughly ten species of *Tithonia*. popular names are giant Mexican sunflower, Japanese sunflower, Mexican sunflower, shrub flower, tree marigold etc. Some of the local names in Nigeria includes: Sepeleba, June 12, Express etc (Figure 2.2). *Tithonia diversifolia is a* stoloniferous, annual or perennial herb or succulent shrub with a woody texture that can grow up to 2 or 3 meters in height (Gualberto *et al.,* 2011). Its taproot has a lot of tiny secondary roots (Mwango *et al*., 2014).

Figure 2.2 Mexican Sunflower- (*Tithonia diversifolia* (Hemsl.) A. Gray)

The leaves are subovate, alternating or opposite, thickly hairy, and measure 5–17 cm long by 3.5–12 cm wide. Up to six enormous yellow flowers with a diameter of 12 cm conceivably generated on a single ripe stem (CABI, 2014; GISD, 2012; Orwa *et al.,* 2009). It is one of the most effective flowers for luring butterflies. and even hummingbirds is the Mexican sunflower. A grove of *Tithonia* may provide supplies for construction as well as a home for chickens and at least a half-dozen butterflies. (Olabode *et al*., 2007; Devide, 2013; CABI, 2014). In some places, it is regarded as a weed (GISD, 2012). Akinyemi *et al*. (2009) reported that *Tithonia* was found to have the greatest favorable impact on nematode decrease. Its use in conjunction with fertilizer would be beneficial to plantain growers because it reduces nematode populations while also increasing plantain productivity.

As a result, agricultural management strategies that maintain soil moisture and provide crops with necessary water during dry seasons, as well as prevent the soil from erosion during erosive storms, are needed. A nutrient-rich (N, P, and K) biomass is produced by Mexican sunflower, and reports from Africa and Brazil indicate that it has a favorable impact on succeeding rice and maize crops (Jama *et al*., 2000; Olabode *et al*.,2007; Devide, 2013). Because of its abundance, flexibility, quick growth, with a very rapid turnover of vegetative matter, it is a species with the potential to restore and revitalize soil through the use of green manure or as a sizable amount of compost manure falling on one or more petals. Sunflowers from Mexico are a lovely addition to any garden, having the ability to fill the back border of a flower bed and make a gorgeous cut flower for floral arrangements. Because of its high protein content, it is great for ruminants and rabbits but not as good for chicken and pigs as fodder. Pigs and chickens have been used to investigate the presence of fiber and antinutritional components (Orwa *et al*., 2009; Gualberto *et al*., 2011). Mexican sunflowers are employed in many different applications, such as ornamental, fuel, compost, land demarcation, soil erosion control, and soil remediation. According to (Taiwo and Lawrence, 2014), Both *Tithonia* and *Chromolaena* weed enhanced overall porosity and soil moisture content while decreasing soil bulk and temperature. They also boosted the organic matter and nutrient levels in the soil, which led to great crop growth and production.

2.8 Agricultural Wastes

2.8.1 Cassava peel

Evenson (2003) reported that in Africa, a significant food crop is cassava, it is cultvated on 11 million of the 16 million ha of the continent. Latin America has 2.4 million ha under cultivation, while Asia has 3.3 million. As a result, cassava is entirely grown in tropical countries of which Nigeria is a major producer from the continent of Africa. Cassava is a staple meal in southern Nigeria, where it is primarily consumed in processed forms such as gari, starch and akpu. Ayoade (2013) reported Cassava is the most widely planted crop in Nigeria's southern region, especially among small-scale farmers. It is crucial to the rural economy's food security due to its tolerance of drought as well as its capacity to produce in poor soil conditions. Nigeria is the world's top producer of cassava with about twenty six million tonnes (Aderemi and Nworgu, 2007). Cassava is a staple food in both rural and urban cultures, moreover, it is offered in both fresh and treated versions (IITA, 2004). In Nigeria's rural areas, cassava-based dishes are the most popular. According to the Collaborative Study of Cassava in Africa (COSCA), at least once a week, 80 percent of Nigerians in rural regions consume cassava meal (Nweke *et al.*, 2002). According to FAO, (2019); Nigeria produces around 60 million metric tonness of cassava per year from a farmed area of about 3.7 million ha, making it the world's greatest producer. After the plant is harvested, cyanogenic glucocides, which are present in cassava, decompose into hydrocyanic acid (HCN). This makes unprocessed cassava very poisonous for animal and human consumption (Cooke and Coursey, 1981). Cassava undergoes processing to remove the poison, reduce its toxicity, improve its flavor, and lengthen its shelf life. Peels from cassava can make up from 5% to 15% of the root (Aro *et al.*, 2010). Cassava peel (Figure 2.3).

Figure 2.3 Heaps of cassava peels at garri processing unit

2.8.2 Poultry manure

Poultry manures are waste generated in poultry house on daily basis. It is one of the farm wastes that have both economic and second-hand value. Poultry manure is a bye-product in poultry that its value has not been fully utilized in crop production and agricultural input sustainability. The supply of poultry manure is stable and constant especially from poultry farms across the country. Poultry manure is the most useful as well as beneficial of all livestock manures used as plant fertilizers and soil additives (Charles and Donald, 2012). William (2017), noted due to its high nutrient content, poultry manure has the potential to be a very effective fertilizer. All 13 of the necessary plant nutrients required by plants are present in poultry manure. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe) and molybdenum (Mo) (NRAES, 1999). John *et al*. (2017) noted that in poultry manure, not all of the nitrogen is immediately available for utilization by plants. The nitrogen that plants can utilize is referred to as the plant available nitrogen (PAN). Manure may contain ammonium-N, organic-N, or nitrate-N forms of nitrogen (N).

The ammonium ($NH4^+$) type of nitrogen makes up a percentage of the nitrogen in poultry manure. In relation to pH, ammonia ($NH3^-$) and $NH4^+$ can rapidly exchange. At a pH higher than 6.5, ammonium will turn into ammonia. The amount of ammonia increases and the amount of acid decreases as the pH rises (more alkaline or less acid). The pH of most manure is around 7.0. Ammonium and a trace amount of ammonia are therefore present. Ammonia ($NH3^-$) is a gas that easily evaporates into the atmosphere. Evaporation is a process that is analogous to volatilization. Anytime manure is exposed to air, its surface can experience losses due to volatilization. In the home, in storage, and after it has been applied to the ground, ammonia-N can be lost from trash. (John *et al.,*2017). The relative ratios of nutrients in green manure, however, could make its application problematic. These qualities can be enhanced by initial composting of this material, and the resulting compost material can be kept for prolonged periods of time and is simpler to apply in the field than unprocessed chicken litter.

Biogas generation is one of the economic value of poultry manure in the recent decade, the use of which has not gained general acceptance and use. Effluents derived after biogas generation or the whole use of poultry manure has great potential in turning and ameliorating our soil for sustainable crop production. Alasiri and Ogunkeyede (1999) reported that poultry manure contains nutrients and organic material that can be utilized to improve soil and prepare it for crop nutrient supply, leading to increased crop yields. With the exception of N which comes in a variety of forms; sand can be lost due to a variety of management or environmental factors, other nutrients in poultry manure are in consistent supply. The majority of the nitrogen in chicken manure is present as uric acid, which during storage transforms into urea and eventually gaseous ammonia, which is then volatized under poor storage circumstances (Soilfacts, 2012).

Because both solid and liquid excreta are emitted at the same time, poultry manure is rich in organic content, preventing urine loss. As manure decomposes and mineralizes, the organic N fraction becomes increasingly available for crop absorption. Depending on the environmental circumstances, mineralization rates might range from 40 to 90 percent (Charles and Donald, 2012). According to Mohamed *et al.* (2010), Animal and agricultural experts have been motivated to create and enhance the waste disposal system as a result of growing public awareness of environmental contamination, recycling waste nutrients as efficiently as possible. Recent research has shown that composting poultry feces can produce a stable final product with little nutrient loss.

2.9 Composting

According to Misra *et al*. (2003) composting happens naturally in which microbes 'rot' or decompose organic waste under controlled conditions. Crop residues, animal wastes, food waste, some municipal wastes, and acceptable industrial wastes, after being composted, improve their suitability for use as a resource for soil fertilization.

Compost contains a lot of organic materials. To sustain soil fertility, soil organic matter is essential and, as a result, for long-term agricultural production. It improves the soil's physical, chemical, and biological properties. In addition to providing plant nutrients, it's an excellent approach to obtain cementing agents. These enhancements have as a result, has made the soil (i) grown more stress-resistant, including drought resistance., disease, as well as the danger of being toxic; (ii) aids the crop in better nutrient uptake; and (iii) has a nutrient possessing active properties and cycle capacity due to strong activities microbes. Farmers benefit from these advantages in the form of reducing cropping risks, yields are higher, and inorganic fertilizer costs are lower. Prior to application, composting poultry manure may increase nutrient constituent ratios, generate a more consistent and reliable source of N and P, and ensure that it is just as readily available after composting as fresh litter material (Williams, 2017).

2.9.1 Types of Composting

Considering how the process of breakdown works, composting is classified into two types. Anaerobic composting occurs when oxygen (O) is absent or insufficient, which results in decomposition. This process is dominated by anaerobic microbes, which create intermediate molecules including methane, organic acids, hydrogen sulphide, and other substances. These substances accumulate rather than decompose in the absence of oxygen. Numerous of these compounds have offensive scents, and some of them are poisonous to plants. Low temperatures used in anaerobic composting prevent bacteria and weed seeds from being destroyed. Additionally, the process takes longer than aerobic composting. Usually, these negative aspects outweigh the advantages of this approach, such as the lower amount of labor required and the lower quantity of nutrients lost throughout the process. In the presence of a lot of oxygen, the aerobic composting process is carried out. By breaking down organic molecules, aerobic bacteria create CO_2, ammonia, water, heat, and humus, a rather stable organic byproduct. Aerobic microorganisms further break down organic acids and other intermediate molecules even though they are produced during aerobic composting. Due of the organic elements' rather unstable state, the resulting compost has a low risk of phytotoxicity. Proteins, lipids, and complex carbohydrates like cellulose and hemicellulose all degrade more quickly in the presence of heat. The processing time is shortened as a result. If the temperature is high enough, this technique can also eliminate weed seeds and a range of bacteria that cause illnesses in people or plants. Anaerobic composting is less profitable and deemed less effective for agricultural production than aerobic composting, despite losing more nutrients from the materials (Misra *et al.*, 2003).

2.9.2 The Process of Aerobic Composting

The construction of the pile is the first step in the aerobic composting process. The temperature frequently increases quickly to between 70 and 80 °C during the first several days. Mesophilic organisms (optimum growth range = 20–45 °C) initially multiply efficiently on easily available amino acids and carbohydrates. Their metabolism generates heat. Their own efforts are hampered because of how much the heat is intensified. A few thermophilic bacteria and fungi continue the process, raising the substance's temperature to 65 °C or more (optimum growth temperature range = 50-70 °C or more). During this moment of maximum heating, pathogens and weed seeds are destroyed by the heat, this is crucial for the quality of the compost. The curing stage follows the active composting period, wherein the pile's temperature progressively drops. When turning the pile no longer reheats it, this phase begins, and a new fungus genus that thrives in heated settings arises. These fungi speed up the breakdown of the plant's cell wall components including cellulose and hemicellulose. Composted material that has been cured shields plants from issues of using premature compost with insufficient nirogen (N), O deficiency, and organic acid toxicity. After a while, the temperature decreases to that of the surrounding atmosphere. Despite the fact that the mesophilic microbes reoccupy the compost, the pile becomes more homogeneous and biologically less active once it is finished composting. The substance's color shifts from dark brown to black. With a soil-like texture, the particle materials grow smaller and more homogenous. With an increase in the volume of humus created, the carbon-to-nitrogen (C:N) ratio falls, the pH balances, and the material's exchange capacity rises.

2.10 Factors that influence Aerobic Composting

2.10.1 Aeration

Aerobic composting necessitates a lot of oxygen, especially in the beginning. Aeration is an oxygen supply, hence aerobic composting requires it. Aerobic bacteria' growth is inhibited when oxygen is scarce, resulting in a delay in breakdown. Aeration also eliminates gases, water vapor, and heat that have been stuck in the heap. In hotter climates, heat removal is very crucial where there is a higher risk of overheating and fire. Therefore, sufficient aeration is required for effective composting. Controlling the material's physical characteristics, such as its granularity and moisture content, as well as ventilation, a sufficient rotation frequency, and taking into account the pile size, are all options.

2.10.2 Moisture

Moisture is required for the microorganisms' metabolic activities to continue. A moisture content of 40 to 65 percent is recommended for compostable materials. Composting takes slower when the pile is too dry, while anaerobic conditions result when the moisture content is higher than 65 percent. In practice, a moisture content of 50–60% should be used to start the pile and 30 percent should be used to end it.

2.10.3 Nutrients

Microorganisms require carbon, nitrogen, phosphorus (P), and potassium (K) as their basic nutrients. Particularly crucial is the basic materials' C:N ratio. Although 20:1 and 40:1 ratios are also suitable, raw material C:N ratios should be between 25:1 and 30:1. When the ratio exceeds 40:1, microbial development is constrained and the composting process takes longer. N is underutilized the surplus is Ammonia or nitrous oxide is released into the atmosphere, which exacerbates odor problems, when the C:N ratio is lower than 20:1. The final product should have a C:N ratio of between 10:1 and 15:1.

2.10.4 Temperature

Mesophilic and thermophilic temperatures are used for composting. While 20–45 °C is suitable for the initial composting stage, for later stages, temperatures between 50 and 70 °C may be ideal when thermophilic organisms take over. The aerobic composting process is characterized by high temperatures, which indicate active microbial activity. Pathogens are generally killed at temperatures of 55°C and above, while weed seeds require a temperature of 62°C to be eliminated. Temperature can be controlled with turnings and aeration.

2.10.5 Lignin content

Plant cell walls contain lignin, which has a complex chemical composition that renders it very resistant to microbial attack (Richard, 1996). Lignin's structure has two ramifications: The first is that the bioavailability of other cell-wall components is decreased by lignin, leading to a lower C:N ratio than previously believed (i.e., the ratio of biodegradable C to N). Lignin has the additional benefit of increasing porosity, which simplifies the process of aerobic composting. As a result, while adding lignin-decomposing fungi may boost accessible C, It may speed up composting and, under certain circumstances, reduce N loss, but it may also produce a greater actual C:N ratio and poor porosity, both of which prolong the composting process.

2.10.6 Polyphenols

Hydrolysable and condensed tannins are examples of polyphenols (Schorth, 2003). Condensed tannins that are insoluble attach to proteins and cell walls, reducing the physical and chemical accessibility to decomposers. Proteins interact with soluble, condensed, and hydrolyzable tannins, reducing microbial oxidation and, subsequently, N release. Polyphenols and lignin, two inhibitors, are becoming more popular. According to Palm *et al.* (2001), the chemical make-up of these two substances should be used to group organic waste into groups for better and more robust natural resource management, including composting, on the farm.

2.10.7 pH value

The pH level should not be higher than eight, despite the fact that a wide variety of pH levels can be tolerated by composting thanks to its built-in buffering function. More ammonia gas is created with higher pH values, albeit some of it might escape into the atmosphere.

2.11 Fermentation

There are two forms of fermentation: aerobic therapy and anaerobic treatment. Anaerobic treatment is the breakdown as well as the anaerobic bacteria's ability to stabilize organic molecules without oxygen. Because of the slow anaerobic response, to complete the fermentation process, anaerobic treatment requires more time, which can take up to 10 months. Aerobic treatment is the decomposition and stabilization of organic components in an air-rich environment by aerobic microorganisms. This treatment necessitates maintaining a specific oxygen content in the mixture via mechanical ventilation and stirring. In a shorter length of time, aerobic treatment creates compost.

As a result of the less complex technology required and the greater potential for developing countries to set up and run composting facilities, this guideline concentrates on aerobic fermentation. Temperature, oxygen availability, moisture content, pH, C/N ratio, particle size, and degree of compaction are all factors that affect the efficiency of the fermentation process (Onwosi *et al.*, 2017). By combining organic waste and incorporating moisture as required, these properties can be preserved and enhanced. (Getahun *et al.*, 2012). Blowing or sucking air into the mixture's bottom is a fantastic additional strategy for enhancing aerobic fermentation by supplying oxygen. Anaerobic conditions develop when trash is excessively moist because it cannot absorb air. Heat from fermentation is produced as a result of the moisture evaporating, the moisture content of the raw materials is also lowered. Due to biological deterioration, organic components are degraded to about 50 % throughout the fermentation process, and the moisture content of the raw materials is also lowered.

2.12 Compost

Farmyard manure is made up of animal excreta and bedding material, whether or not the animals are housed in stables (straw or grass is most commonly used). Organic manure from a farm is highly beneficial. Farmyard manure has the following characteristics and effects: It's packed with vitamins and minerals. In manure, just a small portion of the nitrogen is readily absorbed by plants; as the manure decomposes, the remainder is determined. In the short term, animal urine has nitrogen that are available and can be used. A well-balanced fertilizer source for plants is formed when dung and urine are combined. the predominant nitrogen type found in animal dung with a high solids content (at least 10 % total solids) is organic nitrogen (organic-N). Plants cannot use organic nitrogen until it has been broken down by bacteria into ammonium nitrogen. The process of mineralization is the one that organic nitrogen is transformed into ammonium-N. Not every organic N gets mineralized, and the conversion of organic nitrogen to ammonium nitrogen takes time.

A slow-release N source is sometimes used to describe animal manure with a high solids content because the organic-N is released gradually rather than all at once. Many variables, including as soil temperature, soil moisture, soil pH, kind of manure, and the degree of assimilation, affect how quickly and fully this happens. In the first growth season, between 30 and 80 % of the available nitrogen is organic (John *et al.*, 2017).
Farmyard manure has phosphate and potassium levels that are comparable to artificial fertilizers. Phosphorus is abundant in chicken feces. However, knowing where the manure comes from is critical, because heavy metals have been found in the faeces of chickens in traditional farms. By increasing soil organic matter, organic manures help to improve soil fertility. By weight the components' carbon to nitrogen ratio A good ratio to employ is 30 parts carbon to 1 part nitrogen (30:1) (Muller-Samann and Kotschi,1994). If there isn't enough nitrogen in the compost, the process slows down, and a surplus of

nitrogen can lead to the emergence of NH_3 gas, which can cause unpleasant odors (Kubota and Nakasaki, 1991).

Environmental pollution is reduced by recycling organic waste into fertilizer for crop development (Sridhar and Adeoye, 2003). According to Chen *et al.* (2011), compost is the end result of Organic compounds which are decomposed in a controlled biological manner. Compost is a stable, humus-like compound that results from the biological breakdown of organic waste in regulated settings. Human control in the process of biological breakdown is what differentiates composting from natural breakdown of organic materials. Akanbi (2007) reported that Cassava peel compost can be used in a number of ways and adequately for celosia production.

The total nutritional content of manure or compost can be determined through examination, but the breakdown and minerals that are readily available for plant growth is influenced by the release pattern of organic components. In general, the first year following application, manure will be the primary source of phosphate (70–80%) and potassium (80–90%) (Wan Rashida *et al.*, 2004).

Gabriel *et al*. (2014) concluded that surface-applied composts' ability to control weed growth is a key feature. Weeds are suppressed by compost either because of its physical presence as a surface cover or because of the phytotoxic substances it contains. This, in addition to its ability to conserve soil water and supply needed nutrients to plant, it also make compost indispensable input under sustainable cropping system Combustible organic compounds consist of complex carbon, nitrogen, hydrogen, and oxygen, which, as seen in proteins and the breakdown products of those proteins, is occasionally mixed with other elements like sulphur and phosphates; or carbon compounds like sugar, cellulose, and hemicellulose; or combinations with calcium, magnesium, and other mineral elements, as in proteins and their breakdown products.

All of these elements are broken down into compost. Microorganisms have 'digested' some or all of these breakdown products, forming new chemicals that are then broken down again. The amount of these breakdowns, new syntheses, and secondary breakdowns that have taken place has a significant impact on how effective composts are as fertilizers. Carbon dioxide and simple nitrogen molecules, such as N_2, NO_2, NO_3, NH_3, and water are the last, end products of all breakdown processes; all of which can be lost in one manner or another. Calcium, magnesium, other nitrates, ammonia salts, carbonates, as well as silicates and aluminates that may be present in the source materials are some examples of simple mineral compounds that develop. As a result, a compost's level of organic material may vary significantly (Ehrenfried, 1984). Ipadeola and Adeoye (2014) reported that fear of procuring inorganic fertilizers by crop farmers is alleviated with the recent trend of embracing and recycling of biodegradable waste products to arable land.

2.13 The best way to store manure from a farm

To obtain high-quality manure, farm manure should be gathered and kept in storage for a period of time. According to Nadia (2015), the optimum outcome is obtained when farmyard waste is composted. Manure stored in anaerobic circumstances (for example, in waterlogged pits) is of lower quality. When animals are maintained in stables, collecting farmyard manure becomes substantially easier. Manure should be combined with dry plant material to absorb the liquid (straw, grass, crop leftovers, leaves, etc.). Long straw absorbs more water than dispersed along the roadside straw that has been clipped or mashed. Manure is normally stored in mounds or pits near the stable. If it is covered with fresh bedding material, it can also be used as bedding in the stable. Farmyard manure should be kept out of the sun, wind, and rain at all times. To reduce nutritional losses, both water blocking and drying out should be avoided.

Watertight storage compartments with a slight inclination are recommended. The ideal condition involves a trench that collects the liquid from the manure pile and the urine from the stable. A barrier encircles the heap, preventing uncontrolled urine and water inflow and outflow (FAO, 2015). In dry places and during dry seasons, storing manure in pits is especially beneficial. When the pile is stored in pits, the risk of drying out is decreased, as is the need to hydrate the pile. However, because the pit must be excavated out, there is a higher risk of flooding and more labor is necessary. This process necessitates the excavation of a 90-centimeter-deep trench with a little inclination at the bottom. Apply the straw after the bottom has been squeezed. Each layer is crushed and coated with a thin layer of earth, with 30 cm thick layers filling the pit. After filling the pit to a height of roughly 30 cm above ground level, 10 cm of earth is added.

2.14 Origin and Distribution of Banana

Indochina and Southeast Asia are home to the largest Musa species found in the wild which are diverse, as well as the group's believed origins, and the earliest domestication of the group is supposed to have occurred here. (Simmonds, 1962). The Indo-Malaysian region, which extends all the way to northern Australia, is where edible bananas first appeared. They were only rumored to exist in the Mediterranean region in the third century B.C. Europe was considerably different in the 10th century A.D. Early in the 16th century, Portuguese seamen carried the plant from the coast of West Africa to South America. Eastern Indonesia may be where Pacific cultivars originated, from where they finally made their way to Hawaii and the Marquesas. Soon after the birth of Christ, plantains and bananas were first brought to Sub-Saharan Africa. Early European explorers of the West African coast made the discovery of the crop and quickly spread over the continent in the late 15th century (Reynolds, 1927). Bananas are farmed on around 10 million hectares around the world, yielding over 81.2 million tons per year (Anon, 2008). It is a crop that needs lots of potassium, phosphate, and nitrogen (Lahav and Turner, 1983; Al-Harthi and Al-Yahyai, 2009; Yao *et al.*, 2009). There are 130 countries where bananas are farmed, mostly in the tropical and subtropical regions of the Southern Hemisphere (FAO, 2008).

Numerous varieties of bananas and plantains are grown for food and profit in the humid tropics. AAB dessert bananas, AAB plantains, and ABB and AAA cooking bananas are among the triploids and hybrids of *Musa acuminata* and *M. balbisiana* that are grown. The Horn-type (AAB) plantains accounted for almost one-third of all plantains produced in 1979 (Stover and Simmonds, 1987). These are some of the nations that cultivate them as cash crops and staple meals: Nigeria, Cameroon, Ivory Coast, Brazil, Colombia, Venezuela, India, Indonesia and the Philippine. AAA cooking bananas are grown principally in the East African countries, Uganda, Rwanda, Burundi and Tanzania.

Gowens (1995) reported triploid plants have several advantages, the most important of which is that they are stronger and more productive than diploids. Triploid bananas make up the great majority of cultivated banana varieties, with AAAs cultivating a plethora of sweeter dessert cultivars (including well-known cultivars for export). Cavendish banana are subgroup of the triploid AAA cultivars of *Musa acuminata*. According to Robinson (1995), the tropical, herbaceous, year-round banana plant has no natural dormancy and needs a lot of water, particularly during warmer weather. Given that it has broad, wide leaves and a high leaf area index (LAI), in comparison to most tree fruit crops, the banana plant has shallow roots, which makes it less able to draw water from drying soil. It also has a high capability for transpiration and a quick physiological reaction to soil dehydration, especially when there is a strong need for evaporation.

Banana plants can be sensitive to even little changes in the amount of water in the soil due to the presence of single or a combination of characteristics, necessitating meticulous irrigation timing. Currently, bananas are produced everywhere in the tropics and subtropics. Unless specific clones are cultivated up to 2000 m in Central and East Africa, they are commonly grown at elevations up to 1500 m between latitudes 30 N and S of the equator (Stover and Simmonds, 1987). Currently, bananas are farmed throughout the entire world's humid tropical areas, and behind grapes, citrus fruits, and apples, they constitute the world's fourth largest fruit production. The global output is predicted to be 28 million tons, with Latin America accounting for 65%, Southeast Asia for 27%, and Africa accounting for 7%. One-fifth of the yield is exported as fresh fruit to Europe, Canada, the United States, and Japan. In Asia, India produces the most bananas. The crop, grown on 400,000 acres (161,878 ha), is only for use in the home. While the Philippines produces nearly half a million tons annually, primarily for export to Japan, Indonesia produces about two million tons annually. Taiwan harvests over 500,000 tons for export.

In Tropical Africa (mostly the Ivory Coast and Somalia) every year, nearly 9 million t of bananas are produced, with a sizable export market in Europe. Brazil is South America's biggest banana grower, Colombia and Ecuador are the largest exporters, approximately 3 million tons annually for regional use. In 1980, Venezuela produced 983,000 tons. Large-scale commercial production for export to North America has been concentrated in Honduras, Panama, and to a lesser extent, Costa Rica. (where banana fields can cover 60 square meters). Martinique and Guadeloupe, the Windward Islands, are the primary cultivators in the West Indies, and they have long exported to Europe. The staple food of the people of Western Samoa is green bananas, which are exported in enormous quantities (Morton, 1987). In the previous 30 years, banana output in Africa has doubled to 10 million metric tons, while it has quadrupled in Asia to 62 million metric tons.

Almost every African country produces a substantial number of bananas, but only a few export them. Almost all of Africa's banana exports come from West Africa. Over the last 15 years, this region's banana production has exploded, accounting for roughly 4% of global banana commerce. In West and Central Africa, the bulk of the 70 million people rely on Musa fruits for their daily carbohydrate needs (Rowe, 1998). For Nigerian subsistence farmers, bananas and plantains are significant food and revenue sources. There has been an increase in the production of large-scale crops (Obiefuna, 1986). There are numerous new production zones in addition to the conventional humid rainforest production zone, are found in southern Nigeria's sub-humid lands (Baiyeri and Ajayi, 2000). According to reports by MoA (2006), the 'Williams' cultivar is the most extensively grown banana, yielding an average of 62.3 t/ ha compared to the 'Dwarf' and 'Giant Cavendish' cultivars (39.7 and 33.6 t/ ha respectively). To this effect Federal Government of Nigeria in conjunction with Federal Ministry of Agriculture imported tissue culture banana from Costa-Rica. This cultivar was new in Nigeria as at the time of introduction so the plantlets were adequately quarantined at NIHORT being the mandate Institute. This research work benefitted from the gesture of NIHORT management.

2.15. Climatic requirements of Banana

Morton (1987) discovered that edible bananas are only found in tropical or near-tropical locations, typically between 30° N and 30° S latitudes. There are several climates in this range, each having a varied dry season duration as well as various levels and patterns of precipitation. A favorable climate for bananas has an average monthly rainfall of 10 cm and a mean temperature of 26.67 °C (Akinyemi *et al.*, 2010). The dry season should not last more than three months. Growth is slowed by cool weather and extended dryness. In the dry season, only one leaf is produced monthly by banana plants, however in the wet season, they generate four leaves per month. If the temperature drops below freezing right before flowering, It is possible that the bud can't break through the stem. If the fruits have already formed, maturation may be delayed for a while or even stopped altogether. Leaf emergence rate is the most visible phenological event in bananas, and it is strongly controlled by temperature (Matt and Mellinda, 2016).

2.16. Nutritional requirements of Banana plant

According to Shahmir *et al*. (2014) Nitrogen, phosphorus, and potassium are major or macronutrients that are required in substantial proportions, yet soils are typically low in these nutrients, especially in fragile tropical soils. Banana plants require a sufficient amount of nutrients to flourish. Nutrients that are needed in large quantities include nitrogen, potassium and magnesium (Pius and Marion, 2004). Being that it is a component of several plant proteins, nitrogen is crucial for banana nutrition. As a part of the chlorophyll molecule, nitrogen participates in photosynthesis through a number of enzymatic processes. Phosphorus is found in nucleic acids, phospholipids, and the plant's energy storage and transmission system. It is required in large concentrations at the root and shoot growth sites.

A substantial of major nutrients, such as nitrogen, phosphorus, and potassium, are required by banana (Twyford and Walmsley, 1974). Since over 60 enzymes involved in plant growth require potassium to function, it is the most crucial nutrient for banana production, carbohydrate formation, sugar translocation, many enzyme functions, production, quality standards, banana storage duration, and disease tolerance, abiotic stress resistance, cell permeability, and a variety of other functions. No plant structure or chemical molecule contains potassium, despite being essential for nearly all biological activities and catalyzing vital metabolic processes, such respiration, photosynthesis, starch synthesis, stomata regulation, and nutrition and water intake management. Potassium is required for cell division and expansion at all phases of development, but especially during fruit development. Cell division and expansion, which are important activities, have an impact on fruit size. They control water uptake and, as a result, other nutrient uptake by controlling stomata opening and closing. Stomata are leaf structures that promote gas exchange for photosynthesis, and water transport from the roots to the leaves aids in the motion of carbohydrates between the leaves and the fruits.

Potassium is required the most during fruit development. In the soil and in plants, potassium is especially mobile, and just before bunching, it is absorbed during the latter phases of vegetative development. Potassium absorption is reduced after bunching. Potassium is rapidly leached from lighter soils and should be applied more often. Potassium competes with other cations for absorption, including calcium, sodium, and magnesium. Yellowing of older leaves or leaf tips, which can lead to early leaf loss, is the most common sign of potassium shortage (Matt and Mellinda, 2016). Several researches (Memon *et al.*, 2010; Nyombi *et al.*, 2010; Okumu *et al.*, 2011; Silva *et al.*, 2013; Taulya, 2013) shown that K has a key role in improving banana yield and fruit quality, and several countries that farm bananas have created more effective fertilization techniques (Lopez and Espinosa, 1998; Memon *et al.*, 2010; Nyombi *et al.*, 2010).

For appropriate nutrition, growth, and high-quality banana production, bananas require a greater amount of potassium. In a 70 ton /ha crop, the loss of K from the soil during fruit harvest alone is estimated to be 400 kg /ha/ yr (Lopez and Espinosa, 1998). As a result, Banana nutrition requires high demand and concentration of potassium. In banana nutrition, potassium is extremely important (Turner *et al.*, 1987). For appropriate nutrition, growth, and high quality banana output, bananas require a greater amount of potassium (Noor-un-Nisa, 2010). According to Zake *et al*. (2000), applying at least 200 kg K /ha of fertilizer increased the production by double, implying that one of the issues for the country's declining banana yield could be a lack of potassium in farmers' farms. The first mention of the banana plant, the plant's sap exhibited a high potassium concentration. This finding has since been validated in a number other nations (Twyford,1967). The emergence of an orange-yellow color in the oldest leaves, followed by fast desiccation, is the most common indication of potassium shortage. According to Adeoye *et al*. (2001), In Nigerian soils, potassium (K), a priceless agricultural chemical, is rapidly reduced and fixed. Because no supplies are known to exist in Nigeria, farmers are reliant on imported muriate of potash (KCl). If the soil's potassium release rates do not meet the plant's seasonal demand for potassium, a potassium deficit could occur unexpectedly.

The plant may tend to fruit well, however, as potassium is taken from the leaves to suit the needs of the developing fruit, the leaf system may suddenly collapse (Turner and Bull, 1970). According to investigations of potassium uptake in the field, the overall potassium concentration in the dry matter of the entire plant drops from sucker to fruit harvest. Early in the plant's life, potassium intake outnumbers dry matter accumulation. When potassium supplies are scarce in the early vegetative phase, the maximum potassium uptake rate occurs. During the final phases of the vegetative phase, significant amounts of potassium are absorbed in excess (Twyford and Walmsley, 1973) can have a one-of-a-kind impact on the maturing process (Fox, 1989). It is appropriate to consume potassium in order to supply the primary plant produce's needs throughout its life cycle. when potassium availability is sufficient however, because with ratoon stools, the mother plant and her offspring can be seen simultaneously, it is of no consequence to them.

Sathiamoorthy (2007) reported that fresh plant leftovers from banana orchards decompose, giving the plant potassium it needs to develop. Potassium regulates the transfer of nutrients to the xylem. When potassium supply is insufficient, nitrogen, phosphorus, calcium, magnesium, sodium, manganese, copper, and zinc movement across the xylem is limited (Turner, 1987). The exception is potassium, which travels to the apex of the plant in a consistent proportion regardless of potassium supplies. Banana also require other types of nutrients in small quantities such as phosphorus, calcium, sulphur and other rare elements which are normally found in sufficient quantities in the soil. For this reason, there is no need to add all these minerals to the soil (Pius and Marion, 2004).

2.17 Inorganic fertilizer recommendation for Banana

As stated earlier, Banana originated from South East Asia (Frison and Sharock, 1998). There is need to understand how the crop is being grown productively in other continent compared with Africa that is also contributing to world production. There are different fertilizer recommendations to different geographical and edaphic zones. To ensure that banana plants develop vigorously, they require nitrogen, phosphorus, potassium in a 3:1:6

ratio, as well as other micronutrients. There are so many fertilizer recommendations for banana production across zones and landscapes of the world. The recommendations were based not only on banana nutrient demand but also on the soil available nutrients and other environmental factors prevailing in the growth area. Different studies, however, have advised a wide range of fertilizer rates. According to Ognyan (2016), inorganic fertilizer consumption varies dramatically between continents. In 1994/5, East Asia consumed more than 216 kg of fertilizer per hectare, while South Asia consumed 77 kg, Sub-Saharan Africa consumed 10 kg, and Latin America consumed 65 kg (Vladeva, D., and O. Kostov 2002). A. Rozita, K. Hoi, and O. Kostov are Rashida Kadir, A. Rozita, K. Hoi, and O. Kostov (Rashida Kadir, A. Rozita, K. Hoi, and O. Kostov, 2004; Kostov, O. 2008). Bhatti *et al*. (1995) 455-227-494 kg /ha is the recommended fertilizer rate.

The average N, P, and K rates were reported to be in the Kot Ghulam Muhammad area (25° 17' N, 69° 14' E) was 169-68-21 kg /ha in traditional practice and 492-156-325 kg /ha /yr when management is being watched more closely. Yao *et al*. (2009) found that optimum fertilization for mother banana plants was 900-270-1080 kg N-P_2O_5-K_2O /ha for a yield of 40.5 t /ha, and 825-248-990 kg N-P_2O_5-K_2O /ha for a yield of 58.2 t /ha for the daughter plant. According to Hongwei *et al*. (2004), with a maximum K rate of 1,832 kg K_2O /ha, a maximum production of 39.3 t /ha was achieved. Noor *et al*. (2010) reported farmers cultivating bananas used 437 kg N, 241.6 kg P_2O_5, and 15.4 kg k_2O /ha, according to the study, with a normal manure application of 13 t /ha and an average banana production of 29.3 t/ ha. Furthermore, Hongwei *et al.* (2004) and Yao *et al*. (2009) to attain maximum and high-quality banana yields, researchers used up to 1016 kg N/ ha and 900 kg N /ha, with higher amounts of phosphorus and potassium, respectively.

In Costa Rica, several years of research shown that utilizing 300 to 3320 kg N/ ha /yr of urea in eight split treatments boosted yields and economic benefits on a consistent basis (Lopez, 1991). It should be noted here nevertheless, Nutrients in a readily available form are administered to quickly boost the soil's availability of that nutrient, although not all of them are absorbed by plants or persist there indefinitely (Lodhi *et al*, 2009). For most part of African and west African soils, Hugues (1993), recommended rates varying between 75 and 300 kg/ ha N, 250-600 kg/ ha of potassium, 50-100 kg/ ha magnesium.

2.18 Irrigation / water requirement of banana

According to Turner (1987), the greatest limiting non-biological factor affecting banana output is most likely water. The necessity for irrigation varies by geography, and its commercial justification is determined by the purposes for which a crop is farmed as well as its market worth. When it comes to water shortages, the banana plant is particularly vulnerable, as evidenced by the greenness of its leaves fading. When there is a considerable deficit, the pseudo-stem tissue collapses, causing the plant to topple, when all of the leaves fall off prematurely halfway between the ground and the lowest leaves (Stover and Simmonds, 1987). Two or three times a week, water is applied to ensure that the banana plant gets the most out of its water. This keeps the soil moisture levels in the field between 80 and 100 percent of their maximum capacity (Stover and Simmonds, 1987). According to the study by Purseglove (1978), a minimum of 25 mm of water per week is required for optimal growth, with an average of 2,000-2,500 mm per year being sufficient. Although irrigation appears to increase grower advantages as well as increasing banana harvests on dry land, water scarcity in traditional banana areas necessitates the development of innovative irrigation systems. Understanding the water requirements of bananas on a yearly and seasonal basis is critical in order to build these novel irrigation systems. In shade houses, where irrigation is the plant's only source of water, providing essential water to the plant is critical for its growth and economic production. Drought and soil dryness are unsuitable for the banana plant morphologically and physiologically.

According to Haifa (2020), in banana production, water is perhaps the most limiting abiotic component. By making sure there is sufficient rainfall and artificial water supply, the demanding water needs of this crop may be addressed. Both of these sources are trustworthy and are used in a variety of applications around the world. Banana is a fast-growing plant with high water consumption, having roots that are shallow and spread out, roots having a reduced ability to penetrate the soil, inadequate drought tolerance, physiological responses to a lack of soil water are swift and have a limited capacity to extract water from drying soil. These factors indicate that timing of irrigation is essential since bananas are sensitive to even small variations in soil water content. The soil's ability to retain water, the plant's effective rooting depth, and the portion of the total accessible water that can be reduced before irrigation is allowed determine how much water should be applied, while the irrigation interval is determined by the crop coefficient and evapo-transpiration data. Pius and Marion (2004) reported that banana plants lose a lot of water during the dry season which can seriously affect the size, quality and quantity of the banana bunches to be harvested. Under such circumstances, it is better to water the plants especially the young ones, using furrow water if possible.

Purseglove (1978) reported bananas thrive in climates with 2,000 mm to 2,500 mm of evenly distributed annual rainfall. Wilberforce *et al*. (2001) noted the most suitable rainfall amount is 1500-2500 mm per year, which is evenly distributed. Bananas, on the other hand, can thrive in areas with lower mean annual rainfall levels 1200 mm with proper water management. If rainfall is insufficient or irregular, irrigation is essential. Pius and Marion (2004) recommended 25 mm of water per banana plant every week. In order to avoid wind damage, banana plants thrive best in protected regions. Full sun and a temperature of 27 °C considerably increase plant growth and productivity. Temperatures of 20-21 degrees Celsius with a relative humidity of 90 % are optimum for banana ripening. The banana fruit's internal starch gradually transforms into sugar as it ripens.

2.19. Emphasis on Potassium in Banana production

Tan *et al*. (2004) reported the massive biomass of bananas, as well as the high concentration of K in the fruit, contribute to the crop's high yearly K need. 290 to 1,970 kg K_2O/ha is required for biomass production range from 80 to 200 t/ha. Noor-Un Nisa *et al*. (2010) It was discovered that banana growers place a greater emphasis on nitrogen treatment, followed by phosphorus, and potassium application is virtually completely ignored. In this approach, an imbalance or deficiency in these important nutrients might harm the plant's quality, stress response, and productivity. In a 70 t/ ha crop, the amount of K lost during fruit harvest alone is estimated to be 400 Kg /ha/ yr. (Lopez and Espinosa, 1998). In the work of Noor-Un Nisa *et al*. (2010) growers are allegedly avoiding utilizing K fertilizers because of their high cost. Potassium must be provided via fertilizers, manures, and other sources in order for bananas to have a high yield and good quality. In different banana-producing countries, the rate of application varies between

100 and 1,200 kg of K_2O /ha/yr. Inadequate K reduces total dry matter output and dispersion within banana plants. Since the bunch is the organ most affected by environmental conditions during banana production, the significance of K in banana development becomes even more crucial if superior fruit quality and quantity are required. When bananas are fed enough K, they gain vigor and disease resistance, as well as when the number of fingers per bunch increases, thus does the weight and diameter of the core fruit (Silva *et al.*, 2013). K also speeds up fruit development and shortens the time it takes for a fruit to mature. Potassium also extends the shelf life of bananas.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Location

This experiment was carried out at the National Horticultural Research Institute (NIHORT), Idi-Ishin Ibadan, Southwestern Nigeria on Latitude 7° 23' and 7° 25'N and longitude 3° 50' and 3° 52'E, average temperature 32.2 °C, Relative Humidity (RH) 82 %, 168 m above sea level (asl) with annual rainfall of 1300 mm, experimental plot is on (7° 24' N and 3° 50' E), 163.7 m asl. The soil is Alfisol.

3.2 Cropping history of the Experimental field

The experimental plot has been continously and intensively cultivated for vegetable production in NIHORT experimental field. Over the years, vegetable crops planted includes okra *Ablemoschus esculentus*, fluted pumpkin *Telfairia occidentalis*, Nalta jute or Jute plant *Corchorus olitorius L.* and Green Amaranth *Amaranthus viridis*.

3.3 Soil Sampling and Sample Preparation

Topsoil (0-15 cm) samples were taken at random on the experimental plot with the help of a soil auger. The samples were bulked, mixed, air-dried and sieved (< 2mm). River sand was also obtained from Ajibode river, (University of Ibadan) thoroughly rinsed with distilled water to eliminate impurities, organic fraction, clay and silt. The washed river sand samples and the soil samples prepared were analyzed for characteristics that are both chemical and physical at Department of Soil Resources Management analytical laboratory, University of Ibadan.

3.4 Analyses

3.4.1 Pre-planting soil physical and Chemical properties

Particle size distribution of 2 mm sieved air-dried soil samples taken from a depth of 0 to 15 cm in experimental site was done using Bouyoucos hydrometer method (Sheldrick and Hand Wang, 1993), textural class was determined thereafter. Soil was analyzed for organic carbon, pH, available P, exchangeable bases (Ca, Mg, Na and K), total N, exchangeable acidity (Al^{3+} and H^+) using the manual described in Udo and Ogunwale (1986).

3.4.2 Plant analysis

Matured Siam weed and Sunflower shoot above the soil before flowering were obtained from the proximity of the experimental plot. The above soil plant samples were analysed differently after ashing using methods described by Tel and Hagarty (1984). The ashes were extracted using 10 % HCl and leaf P determined colorimetrically by vanadomolybdate method. Calcium (Ca) and Magnessium (Mg) were determined by Atomic Absorption Spectrophotometer (AAS) and K was evaluated using a flame photometer.(AOAC, 2005). Leaf N was assessed using the micro-Kjeldahl digestion method on fresh plants shoot samples.

3.5 Land preparation and Propagation material

The land used for field experiment was prepared by ploughing twice according to Wilberforce *et al*. (2001) followed by harrowing after two weeks. The land was later marked out for planting with pegs following the layout and plant arrangement for the experiment. Tissue-cultured plantlets of Banana (*Musa cavendish* cv. Williams) were planted on the field at a distance of 2 m x 3 m. Banana were obtained from NIHORT, Idi-Ishin Jericho Ibadan. The banana plantlets (9 weeks old) were two cultivars of Williams Cavendish (Large and Medium).

3.6 **Experiment 1:** Effects of Mexican sunflower (*Tithonia diversifolia*) and Siam weed (*Chromolaena odorata*) mulch on growth and productivity of two cultivars of Williams banana

This set-up was a 2 x 7 factorial experiment- comprising of two cultivars of tissue cultured banana; (Williams: -Large and medium) and seven treatments on a 3,630 m^2 area of land in a Randomized Complete Block Design (RCBD) replicated three times. This gives a total of forty two (42) plots. Each plot had an area of 54 m^2 with sixteen (16) banana plants. The banana plantlets were planted in holes dug to (30 x 30 x 30) cm / hole at a spacing of 2m x 3m (1667 plants / ha). The four at the center of each plot were categorized and used as data plants throughout the experiment. Bananas were planted as shown in the Figure 3.1.

Treatments used in this experiment were:

i. Control (No mulch) = C
ii. Fresh Mexican sunflower = FMS
iii. Fresh Siam weed = FSW
iv. Fresh Mexican sunflower + Fresh Siam weed (½ FMS + ½ FSW) = FMS + FSW
v. Dried Mexican sunflower = DMS
vi. Dried Siam weed = DSW
vii. Dried Mexican sunflower + Dried Siam weed (½ DMS + ½ DSW) = DMS + DSW

Watering of the plants commenced immediately after planting and continued until rainfall was steady. The watering was performed three times a week according to Stover and Simmonds (1987); (3 times) and Wilberforce *et al*. (2001) with ten (10) litre volume to a banana plant at each time of watering totaling 30 litres of water per banana plant a week having considered the field capacity of the experimental area. Watering was performed on Sundays, Wednesdays and Fridays.

3.7 Weight of mulch materials used in ratio

One kilogram (1 kg) fresh weight each of Mexican sunflower and Siam weed were dried in oven to a uniform weight at 70 °C. The resultant dry weights respectively were 96.0 g and 185.4 g. This translates to a ratio of fresh weight to dry weight of 10.4:1 for Mexican sunflower and 5.4:1 for Siam weed. This implies a 10.4 kg fresh weight of Mexican

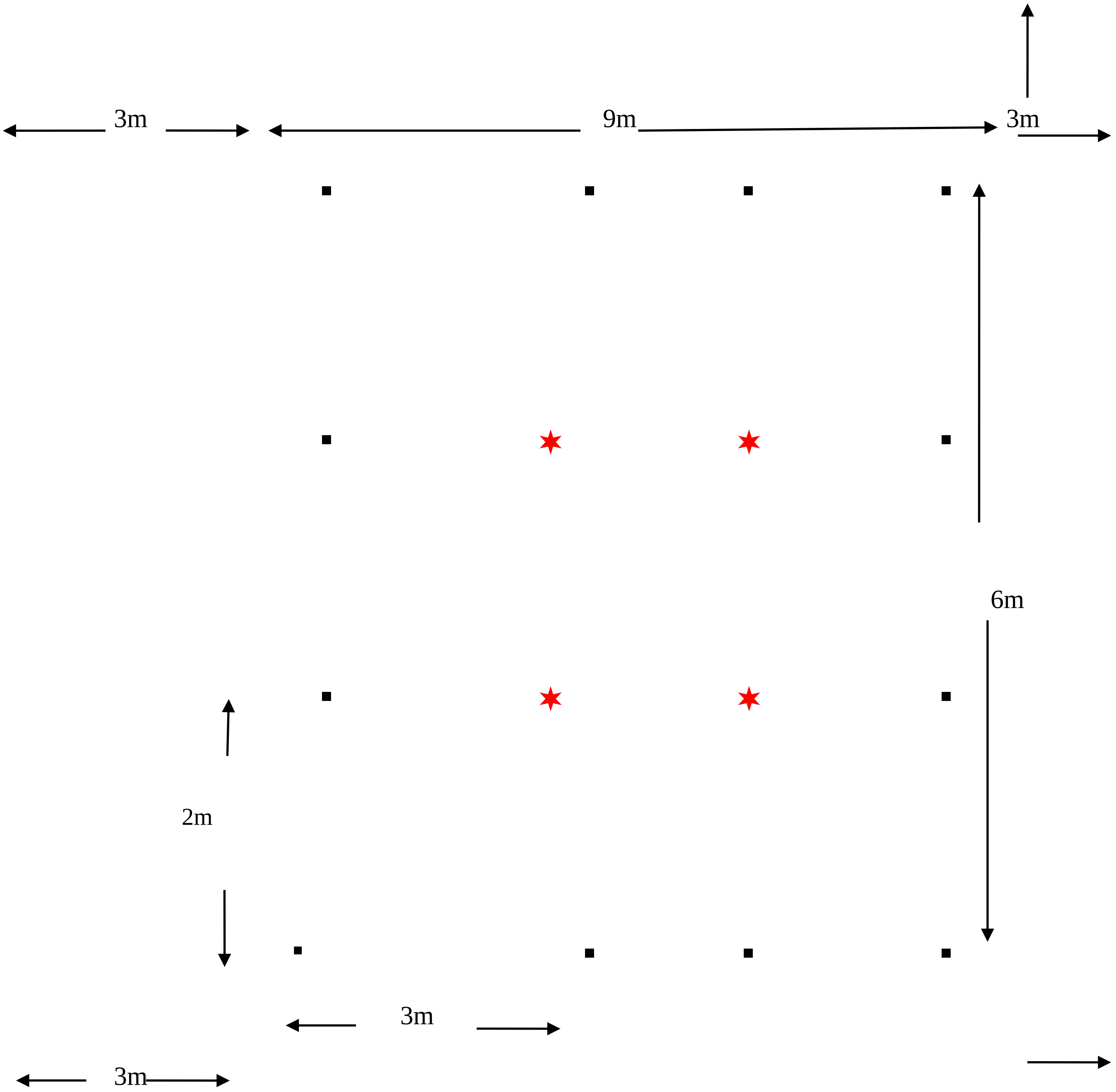


Figure 3.1: Banana Plant arrangement on each plot for experiment 1

▪ Plants on the plot

✶ the four at the middle tagged as data plants sunflower has equivalent dry matter content as 1 kg dry weight of Mexican sunflower. Similarly, a 5.4 kg fresh weight of Siam weed has equivalent dry matter content as 1 kg dry weight of Siam weed.

3.7.1 Application rates of mulch used

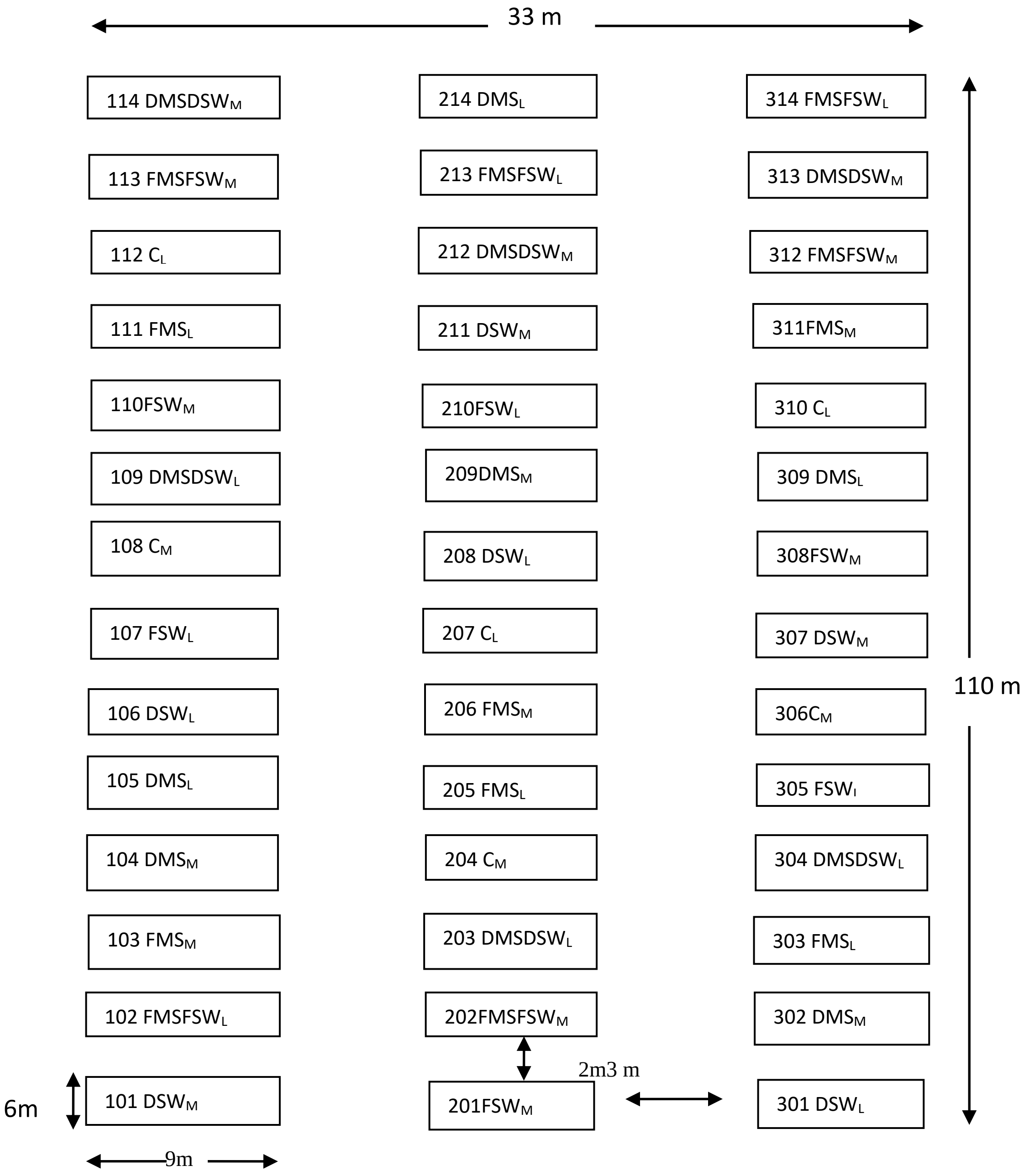
For optimum banana production, Hugues (1993), recommended between 75 and 300 kg/ha N, 250-600 kg/ha of potassium, 50-100 kg/ha magnesium. All applications of mulching materials were referenced with potassium demand of banana (600 kg K /ha), potassium content of the mulching materials (Mexican sunflower and Siam weed) and native available K in the experimental plot. Therefore, the treatments and rates used in experiment 1 were:

i. C= control (No mulch)
ii. FMS=Fresh Mexican sunflower (41.3kg / plant)
iii. FSW=Fresh Siam weed (21.38kg / plant)
iv. FMS + FSW=Fresh Mexican sunflower + Fresh Siam weed (½FMS 20.65 kg + ½ FSW 10.69 kg)
v. DMS=Dried Mexican sunflower (3.97 kg / plant)
vi. DSW=Dried Siam weed (3.96kg / plant)
vii. DMS + DSW =Dried Mexican sunflower + Dried Siam weed (½ DMS 1.99 kg +½ DSW 1.98kg)

The treatments were applied to the two cultivars of banana in the experiment as shown in Figure 3.2. Mulching materials were applied to banana plants in three split dozes at 1MAP (30 %), 5 MAP (30 %) and 8 MAP (40 %) of the calculated rate to the appropriate plots.

3.8. Heaping up

At each mulching operation, heaping up of soil to each of the banana plants in the experimental plots was carried out. These were done to facilitate easy decomposition of the mulching materials. The mulching materials were applied 15 cm away from the banana pseudostem. Soil levels were raised after 3 months of planting and immediately



114 DMSDSW$_M$	214 DMS$_L$	314 FMSFSW$_L$
113 FMSFSW$_M$	213 FMSFSW$_L$	313 DMSDSW$_M$
112 C$_L$	212 DMSDSW$_M$	312 FMSFSW$_M$
111 FMS$_L$	211 DSW$_M$	311FMS$_M$
110FSW$_M$	210FSW$_L$	310 C$_L$
109 DMSDSW$_L$	209DMS$_M$	309 DMS$_L$
108 C$_M$	208 DSW$_L$	308FSW$_M$
107 FSW$_L$	207 C$_L$	307 DSW$_M$
106 DSW$_L$	206 FMS$_M$	306C$_M$
105 DMS$_L$	205 FMS$_L$	305 FSW$_l$
104 DMS$_M$	204 C$_M$	304 DMSDSW$_L$
103 FMS$_M$	203 DMSDSW$_L$	303 FMS$_L$
102 FMSFSW$_L$	202FMSFSW$_M$	302 DMS$_M$
101 DSW$_M$	201FSW$_M$	301 DSW$_L$

Fig. 3.2: Field layout of Experiment 1 plots

Legends

FMS$_M$= 41.3 kg / plant FMS$_L$= 41.3kg / plant FSW$_M$=21.38 kg / plant FSW$_L$=21.38kg / plant
FMSFSW$_M$= 20.65 kg FMS + 10.69 kg FSW / plant FMSFSW$_L$= 20.65 kg FMS + 10.69FSW/ plant
DMS$_M$= 3.97 kg/ plant DMS$_L$= 3.97 kg/ plant DSW$_M$= 3.96 kg / plant DSW$_L$= 3.96kg / plant
DMSDSW$_L$= 1.99 kg DMS + 1.98 kg DSW / plant DMSDSW$_M$ = 1.99 kg DMS + 1.98 kg DSW / plant
C$_L$= No mulch C$_M$= No mulch

Subscript M= Medium banana variety

Subscript L= Large banana variety

14 treatments replicated 3 times

after mulch application to maintain a loose soil. This was done to assisting in the prevention of banana plant fall in case of strong wind.

3.9. Parameters measured

Parameters measured from the field include soil temperature in the morning between 6:30 and 7:45 am and afternoon between 2:00 and 4:00pm at seven hours interval on each day; Soil temperatures were measured at 4, 6, 8 and 10 weeks after planting (WAP). Soil moisture content, vegetative measurements such as pseudostem height taken from soil level using a measuring pole (3 m range), Number of functional leaves (number of fully green leaves with no signs of physiological damage), using the index leaf, the leaf's area was calculated and number of suckers developed was determined by counting. These aforementioned parameters were taken at planting and thereafter monthly. Soil temperature data collection was stopped when rainfall started as the experiment was supposed to be rainfed. Stem girth of the pseudostem was determined at 30 cm in height measured from the base of the plant with measuring tape and diameters were calculated accordingly using the formula:

$D = C/\pi$, where

D is the diameter, C is the circumference and π is a constant (3.143)

$C = \pi D$---------------------------------------**Eqn 3.1**

Leaf length and leaf widest width were taken using every third leaf from the cone leaf (Index leaf). Utilizing the multiplication method of the leaf length and widest width, the leaf's area was determined as described by Murray (1961), with the equation:

Leaf Area (LA) = $0.8 (L \times W)$------------- **Eqn 3.2**

where,

L = Length of the leaf;

W= Widest width of the leaf and

0.8 = a constant.

Samples of soil were taken between 0 and 15 cm soil below mulch at each data plant using a soil auger in every plot. The weights of newly collected soil samples were identified and determined with measuring balance and the corresponding dried weights were also measured after oven drying (105°C) of the soil samples to constant weights.

$$\text{Soil Moisture Content (SMC)} = \frac{\text{Wt of moist soil} - \text{Wt of oven dried soil}}{\text{Weight of oven dried soil}} \times \frac{100}{1} \quad \text{---}\textbf{Eqn 3.3}$$

3.10. Weed control and Borders

Initially, weeds were controlled manually with hoe and cutlass once a month. Later, the use of mechanical slasher (bush cutter) was used fortnightly. Field borders or experimental field edges were also cleared regularly to 3 m from the experimental field round the entire field to prevent fire outbreak during dry season.

3.11 Composting of materials

The weeds used as mulch in experiment 1 were composted with two agricultural wastes (cassava peel and poultry manure) to form five different compost combinations. These composts were tested for nutrient release pattern using washed river sand in an incubation experiment for ten (10) weeks. All composts used in this experiment were prepared according to established procedures adapted by Akanbi *et al*. (2002). Each weed was combined with well cured poultry manure and cassava peels in C:N ratio Carbon to Nitrogen Ratio: 30 to 1 by weight (Muller-Samann and Kotschi, 1994). The compost products were analyzed in the laboratory before usage to determine their chemical makeup and whether they were suitable for use in field experiments. The result of the composts analyses were used to determine the equivalent weight of each compost material that supplied 600 kg K/ha (Hugues, 1993) as recommended for banana.

The composts were

i. cassava peel only
ii. cassava peel + poultry manure
iii. cassava peel + Siam weed

iv. cassava peel + Mexican sunflower
v. cassava peel + poultry manure + Mexican sunflower + Siam weed
vi. cassava peel + Mexican sunflower + Siam weed

They were prepared using perforated plastic containers of 120 litres capacity each. The plant materials were chopped into bits for faster bio-degradation. The materials used were arranged into the containers in layers one after the other. Siam weed was used as the base followed by poultry manure then cassava peel and Mexican sunflower in the last layer. Each layer was wetted with water when added until the container was filled up. All the materials were thoroughly arranged and mixed together following ratio C:N of 30:1 by weight (Muller-Samann and Kotschi, 1994). The composts were turned regularly at five days interval to enhance uniform microbial activities and increase the number of thermophiles especially at thermophilic phase (Active phase). This was done till the composts become odourless and black in colour.

3.12 **Experiment 2**: Nutrient release pattern of the Cassava peel based Compost to Sand sample

.

Methodology: 50 g washed river sand were put into 75 ml cups and mixed with different compost treatments as listed below:

i. Control (No treatment added) = C
ii. Cassava peel = C_P(100%)
iii. Cassava peel + Poultry manure = C_PP_M(70%+30%)
iv. Cassava peel + Siam weed = C_PS_W(70%+30%)
v. Cassava peel + Mexican sunflower = C_PM_S(70%+30%)
vi. Cassava peel + Poultry manure + Siam weed + Mexican sunflower = $C_PP_MS_WM_S$(70%+10%+10%+10%)
vii. Cassava peel + Siam weed + Mexican sunflower = $C_PS_WM_S$(70%+15%+15%)

This study was put up in a Completely Randomized Design with four replications having seven treatments including control. A total of one hundred and forty (140) cups were set up at the same time and constantly watered with equal quantity of water. The recommendation of Akinyemi *et al*. (2004), (15 t /ha of compost / organic fertilizer application) was used because this experiment is intended for sole banana production. This translates into 0.34 g compost into each 50 g washed river sand. These were incubated in the laboratory in the cupboard for a period of ten (10) weeks. Laboratory soil analyses were carried out at 2, 4, 6, 8 and 10 weeks after incubation (WAI) apart from the initial composts and washed river soil analysis before the incubation experiment began. The sand samples extracted (10 g) with the use of spatula 15 mm below the surface of the soil. Analyses of Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) were carried out at 2 weeks interval terminal stage of incubation.

Three composts: Cassava peel (C_p), Cassava peel + Siam weed (C_PS_W) and Cassava peel + Mexican sunflower (C_PM_S)were screened out and the remaining three composts: Cassava peel + Poultry manure (C_PP_M), Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) and Cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$)were taken to the field for next field experiment 3, using the Large cultivar that performed better in experiment 1.

3.13 **Experiment 3**: Evaluation of cassava peel amended composts on growth and yield of (Large) banana cultivar

3.13.1 Land preparation, planting and experimental procedure

At two-week intervals, the field was ploughed and harrowed before marking out for planting operation was performed. Williams Large banana plantlets (192) were planted on a 48 m x 22 m area of land 1056 m^2 in a Randomized Complete Block Design (RCBD) with three replications. Each block had four plots of 54 m^2 each including control. Plant population of each plot was 16 banana plants spaced at a distance of 2 m x 3 m. The four banana plants at the middle of each plot were tagged for data collection in this experiment. The three treatments selected from experiment 2 were: Cassava peel + Poultry manure (C_PP_M), Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) and Cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$). Potassium content of the composts as a reflection of Potassium recommended rate were used to determine the rates of composts applied per banana plant as shown below:

i. C_PP_M = 22.68 kg
ii. $C_PP_MS_WM_S$ = 17.00 kg
iii. $C_PS_WM_S$ = 7.77 kg

Experimental layout is as shown in figure 3.3. The treatments were applied in three split dozes: 1, 5 and 8MAP.A measure of 7 kg each of the compost treatments C_PP_M, and $C_PP_MS_WM_S$ was applied on experimental field to appropriate plots of large banana cultivar, while 2.5 kg of $C_PS_WM_S$ was applied at 1 month after planting.

Second application of the composts to large banana cultivar was carried out at 5 months after planting using7.68 kg of C_PP_M, 3.00 kg of $C_PP_MS_WM_S$ and 2.5 kg of $C_PS_WM_S$. At 8 months after planting, third application of composts materials were applied with 8 kg of C_PP_M, 7 kg of $C_PP_MS_WM_S$ and 2.52 kg of $C_PS_WM_S$ to appropriate plots of large banana cultivar. Weed control was as in experiment 1.

3.13.2 Measurement of parameters

Parameters taken include pseudostem height with measuring pole, stem girth, Number of functional leaves (fully green with no signs of physiological damage), leaf Area using index banana leaf i.e. the third leaf from the cone leaf, Number of suckers developed.

3.14 Statistical analysis

Analysis of variance was carried out on incubation, field responses to mulch (2 factors) and compost using General Linear model (GLM) procedure (SAS software, 2013). The student t-test was computed and compared with the difference of adjacent means of the parameters in the two banana cultivars used. Duncan's Multiple Range Test (DMRT) was also used to separate treatment means on banana plants in the experiments at 5 % probability level.

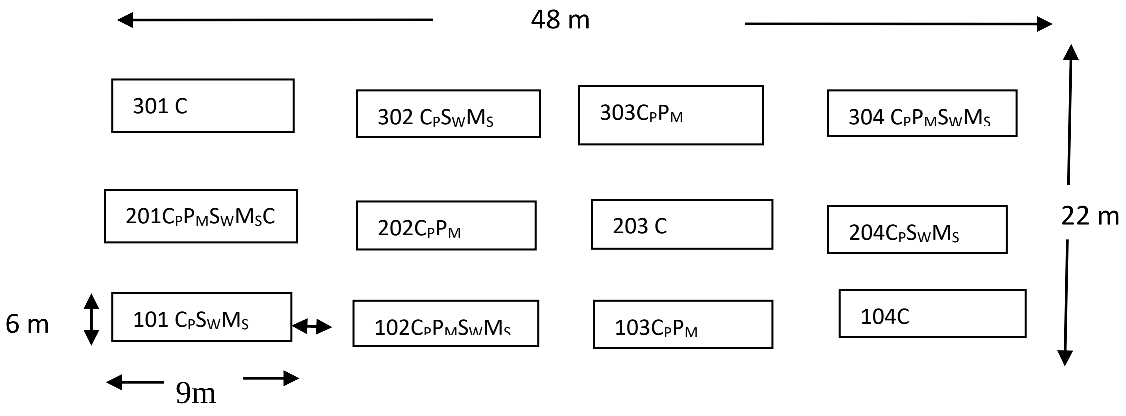


Figure 3.3: Field layout of Experiment 3 plots

Legends

C = No compost , C_PP_M= 22.68 kg

$C_PP_MS_WM_S$= 17 kg $C_PS_WM_S$= 7.77 kg

$P_MS_WM_S$= 21.4 kg

P_MM_S= 23.2 kg

Four (4) treatments replicated 3 three times

CHAPTER FOUR

RESULTS

4.1 Physico-chemical properties of the experimental soil and washed river sand

Table 4.1 shows the routine analyses of the soil taken before planting and the washed river sand. The soil had a mild acidity (pH=6.50), loamy sand while the washed river sand was nearly neutral. The organic carbon was 13.20 g/kg in the soil while the washed river sand contained 5.25 g/kg. The soil and washed river sand contained 28 mg/kg and 4.61 mg /kg available P. 0.3 and 0.0 cmol/kg exchangeable K respectively. The Mexican sunflower contained 22.1 g/kg total N and 2.67 g/kg total P which are higher Siam weed with 9.6 and 2.13 g/kg total N and total P respectively. The Siam weed had higher calcium (225.55 g/kg), magnesium (47.2g /kg) than Mexican sunflower but both plants had similar amounts of potassium (Table 4.2).

4.2 Effects of mulch on Banana (Large and Medium) cultivars

4.2.1. Vegetative phase (2-8 months after planting) of cultivars

The main effect of banana cultivars treated with mulch on average soil temperatures in the morning and afternoon and soil moisture contents are shown in Table 4.3. At 6 WAP, medium banana had significantly ($p \leq 0.05$) lower average soil temperature in the morning than under the large cultivar was lower and significantly ($p \leq 0.05$) different from the average soil temperature of large banana cultivar. At 8 WAP, the early morning and afternoon soil temperature under the Medium cultivar were significant ($p \leq 0.05$), lower than under the large cultivar. These are related to the significantly higher soil moisture content under medium cultivar at 6 and 8 WAP. The height of tallest suckers at harvest recorded for large banana was significantly ($p \leq 0.05$) higher from that of medium banana cultivar. Soil moisture content (%) with medium banana was higher and significantly ($p \leq 0.05$) different from that of large cultivar at 6 WAP and 8 WAP. The

Table 4.1. Physical and chemical properties of experimental soil before cropping and washed river sand used for the incubation study

Parameter	Experimental soil	Washed river sand
pH (H_2O) 1:1	6.50	6.90
Organic Carbon (g/kg)	13.20	5.25
Total Nitrogen (g/kg)	1.20	0.63
C:N ratio	11	8.33
Exchangeable bases (cmol/kg)	2.9	1.7
Ca ‘’	0.7	0.6
Mg ,,	0.3	0.1
K ,,	0.3	0.0
Na ,,	1.6	0.1
Exchangeable Acidity ,,	0.5	0.1
ECEC ,,	3.4	2.3
Available Phosphorus (mg/kg)	28	5
Available micronutrients (mg/kg)		
Mn ,,	8	2
Fe ,,	15	6
Cu ,,	0	0
Zn ‘’	11	1
Particle Size (g/kg)		
Sand‘’	832	954
Silt ‘’	74	29
Clay ‘’	94	17
Textural Class	Loamy sand	Sand

Table 4.2. Proximate analysis (g/kg) of Siam weed and Mexican sunflower

Material	**Total Nitrogen**	**Total Phosphorus**	**Ca**	**Mg**	**K**
Mexican sunflower (MS)	22.1	2.67	55.40	21.8	51.1
Siam weed (SW)	19.6	2.13	225.55	47.2	51.2

Table 4.3. Effects of mulch on the mean morning and afternoon soil temperature and soil moisture content in two cultivars of banana (Large and Medium) at 6, 8 and 10 WAP

Parameters	**Weeks After Planting (WAP)**	**Varieties**		**T-test**
		Large	**Medium**	**$t_{0.025(28)}$**
Soil Temperature Morning (°C)	6	28.52	27.57	0.60*
	8	33.14	32.30	0.41*
Soil Temperature Afternoon (°C)	8	36.01	35.73	0.61NS
Soil Moisture Content (%)	6	12.89	13.24	0.24*
	8	11.77	12.42	0.34*
	10	13.96	14.11	0.23NS

*Significant at $p \leq 0.05$

NS= Not Significant

highest height of sucker at harvest recorded for large banana cultivar was significantly ($p \leq 0.05$) different from that of medium banana cultivar. The main effects of the banana cultivars (Large and Medium) treated with the different mulch materials at 6 MAP are shown in Table 4.4. The respective growth parameters increased with time in the cultivars, except the number of functional leaves produced by the large banana cultivar which was lower at 9 MAP than 6 MAP. The large cultivar plants with significantly taller at 6 and 9 MAP, with thicker stems at 6-8 MAP and larger leaf areas at 6 MAP. There was no significant difference in the number of leaves developed between medium and large cultivar at 6 MAP but there were higher values and significant differences of large banana than medium cultivar on stem girth, leave area and plant height. The numbers of suckers developed by medium banana was more than those of large bananas and significantly ($p \leq 0.05$) different at 6 MAP.

4.2.2. Flowering phase (9-11 months after planting) of cultivars

Stem girth/ stem thickness of large banana cultivar showed a tremendous increase of more than 200 % from 6 MAP to 9 MAP (from vegetative to flowering phase) and significantly ($p \leq 0.05$) distinct from the stem girth of Medium banana cultivar at 6 MAP and at 9 MAP. Medium- banana cultivar produced a significantly ($p \leq 0.05$) more number of suckers from the pseudostem than large banana cultivar. The beginning of flowering phase at 9 MAP (Table 4.5) shows higher and significant ($p \leq 0.05$) differences in plant height, number of leaves, and stem girth in large banana over the medium cultivar. Numbers of sucker developed was higher in medium and significantly ($p \leq 0.05$) different from large banana cultivar at both vegetative and flowering phases.

4.2.3. Fruiting phase (11-14 months after planting) of cultivars and at harvest

During fruiting phase (11-14 MAP) in Table 4.6, stem girth of large banana cultivar increased by 15.3 % from 12 MAP to 14 MAP while stem girth of medium banana cultivar increased by 29.1% from 12 MAP to 14 MAP and the difference were significant ($p \leq 0.05$). Large banana cultivar had tallest height of sucker, biggest bunch weight and highest number of hands per bunch which were significantly different from medium cultivar at harvest (Table 4.7).

Table 4.4. Effects of mulch application on vegetative growth of Williams banana cultivars

Parameters	**Months After Planting (MAP)**	**Varieties**		**T-test**
		Large	**Medium**	
Plant Height (cm)	6	19.03	16.89	1.42*
Stem girth (cm)	6	3.14	2.84	0.22*
Leaf Area (cm^2)	6	446.14	362.24	50.38*
Number of functional leaves NFL	6	6.83	6.97	0.49NS
No of suckers developed	6	0.00	0.27	0.24*

*Significant at $p \leq 0.05$

NS= Not Significant

Table 4.5. Effects of mulch application on flowering phase of Williams banana cultivars

Parameters	Months After Planting (MAP)	Varieties		T-test
		Large	Medium	
Plant Height (cm)	9	26.95	22.89	2.56*
Stem girth (cm)	9	9.00	6.21	0.91*
Leaf Area (cm^2)	9	1048	1100	310.7NS
Number of functional leaves NFL	9	6.74	7.54	0.78*
No of suckers developed	9	0.10	0.82	0.58*

*Significant at $p \leq 0.05$

NS= Not Significant

Table 4.6. Effects of mulch application on fruiting phase of Williams banana cultivars

Parameters	Months After Planting (MAP)	Varieties		T-test
		Large	Medium	
Stem girth (cm)	12	10.98	8.66	1.05*
	14	12.66	11.18	0.97*

*Significant at $p \leq 0.05$

Table 4.7. Effects of plant mulch on banana cultivars at harvest

Parameters	**Varieties**		**T-test**
	Large	**Medium**	**$t_{0.025(28)}$**
Height of tallest Sucker at harvest (cm)	51.55	33.82	6.43*
Bunch weight at harvest (kg)	10.22	9.34	0.15*
Number of hands per bunch	11.77	9.23	0.69*

*Significant at $p \leq 0.05$

4.3 Effects of mulch treatments on Vegetative phase (2-8 MAP) of banana

4.3.1 Morning soil temperature of banana

Table 4.8 shows that the average early morning soil temperature under banana was the least in the control (24.1 ^{o}C) and significantly ($p \leq 0.05$) different from average soil temperature of banana with fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (25.7 ^{o}C), dried Mexican sunflower (DMS) (25.2 ^{o}C), dried Siam weed (DSW) (25.3 ^{o}C) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (25.4^{o}C) treatments used at 6 WAP. At 8 WAP, the average morning soil temperature under banana plants in the control treatment was the least (27.0 ^{o}C) which was not significantly different from Fresh Mexican sunflower (FMS) (27.8 ^{o}C) and fresh Siam weed (FSW) (27.2 ^{o}C). Morning soil temperature of banana with fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (25.7 ^{o}C), banana with dried Mexican sunflower (DMS) (28.3 ^{o}C), dried Siam weed (DSW) (28.3 ^{o}C) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (28.5 ^{o}C). The average morning soil temperatures at 10 WAP with dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) was the highest (30.7 ^{o}C) and was significantly ($p \leq 0.05$) different from the control (C) (29.0 ^{o}C), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (29.3 ^{o}C), dried Mexican sunflower (DMS) (29.7 ^{o}C) and dried Siam weed (DSW) (29.3 ^{o}C). At 12 WAP, average morning soil temperature of banana plants with dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (33.7 ^{o}C) was not significantly different from the control (C) (33.8 ^{o}C) treatment, fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (32.7 ^{o}C) and dried Siam weed (DSW) (32.9 ^{o}C) but significantly ($p \leq 0.05$) different from fresh Mexican sunflower (FMS) (31.0 ^{o}C), fresh Siam weed (FSW) (32.6 ^{o}C) and dried Mexican sunflower (DMS) (32.4 ^{o}C).

4.3.2 Afternoon soil temperature of banana

Banana plants with fresh Mexican sunflower has the least average afternoon soil temperature (27.3 ^{o}C) at 6 WAP and this value was significantly different from banana plants with control treatment (33.7 ^{o}C) and dried Mexican sunflower + dried Siam weed

Table 4.8. Effects of mulch treatments on early morning and afternoon soil Temperature (^oC) in Banana

Treatments	Weeks after planting				
	6	8	10	12	14
	Early morning soil temperature				
C	24.1c	27.0c	29.0b	33.8a	25.8a
FMS	24.9bac	27.8bac	29.8ba	31.0c	25.2a
FSW	24.4bc	27.2bc	29.8ba	32.6b	24.8a
FMSFSW	25.7a	28.7a	29.3b	32.7ba	25.7a
DMS	25.2ba	28.3ba	29.7b	32.4b	24.8a
DSW	25.3a	28.8a	29.3b	32.9ba	25.2a
DMSDSW	25.4a	28.5a	30.7a	33.7a	25.1a
	Afternoon soil temperature				
C	33.7a	35.0a	34.7a	38.2a	34.5a
FMS	27.3c	31.3b	31.8d	35.7b	31.7b
FSW	27.7cb	31.1b	32.7cbd	35.5b	31.8b
FMSFSW	27.8cb	31.3b	33.6b	35.7b	31.7b
DMS	29.1cb	31.4b	32.7cbd	35.6b	31.5b
DSW	29.2cb	32.4b	32.0cd	35.4b	31.3b
DMSDSW	29.5b	31.6b	33.0cb	35.2b	32.3b

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C= control,	DMS=Dried Mexican Sunflower
FMS=Fresh Mexican sunflower,	DSW=Dried Siam weed
FSW =Fresh Siam weed,	DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1
FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1	

1:1 (DMSDSW) (29.5 ^oC). The average afternoon soil temperature of banana plants with all the treatments were not significantly different from each other but different from the control treatment (35.0 ^oC) at 8 WAP. The average afternoon soil temperature in the control (C) was the highest at 10 and 12 WAP (34.7 ^oC) and (34.5 ^oC) respectively which which differed from all other treatments.

4.3.3. Soil moisture content

The average soil moisture content of all the treatments used in the experiment were not different significantly from each other but all the treatments were significantly ($p \leq 0.05$) different from banana plant with control (C) treatment at 8, 10 and 12 WAP (Table 4.9). At 14 WAP, there were no significant effect on soil moisture content under the banana plants. Temperature changes in the soil as a result of the treatments (morning and Afternoon) and soil moisture content at 12 WAP are displayed in Figure 4.1.

Figure 4.2 shows that fresh Mexican sunflower (FMS) are significantly ($p \leq 0.05$) higher on number of functional leaves than the other treatments including the control (C) but was not different from treatment of dried Siam weed (DSW) at 3 MAP. At 6 MAP, the highest number of leaves exhibited by the fresh Mexican sunflower (FMS) produced was (8.17) which different significantly ($p \leq 0.05$) from fresh Siam weed (FSW) (6.53), dried Mexican sunflower (DMS) (6.33), dried Mexican sunflower + dried Siam weed (DMSDSW) (6.42) and control (C) (4.39). Each of the treatments displayed significant ($p \leq 0.05$) difference in banana plant height over the control but the treatments were not significantly different from each other at 3 MAP. Figure 4.3 shows fresh Mexican sunflower (FMS) has height of the tallest plant at 6 MAP (51.28 cm) which was more and significantly ($p \leq 0.05$) different from the control (C) (23.18 cm), fresh Siam weed (FSW) (48.05 cm), dried Siam weed (DSW) (47.02 cm) and dried Mexican sunflower + dried Siam weed 1:1(DMSDSW) (47.13 cm) but there was no significant difference in plant height of banana with treatments fresh Mexican sunflower (FMS) (51.28), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (49.11 cm) and dried Mexican

Table 4.9: Effects of mulch on soil moisture content (%) in Banana

Treatments	Weeks after planting –WAP			
	8	**10**	**12**	**14**
C	7.60b	7.08b	11.18b	16.03a
FMS	13.85a	12.58a	14.40a	15.97a
FSW	14.02a	13.05a	14.55a	15.88a
FMSFSW	13.95a	12.82a	14.43a	16.21a
DMS	13.98a	12.88a	14.60a	16.33a
DSW	13.93a	13.00a	14.45a	15.97a
DMSDSW	14.12a	13.27a	14.62a	15.97a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

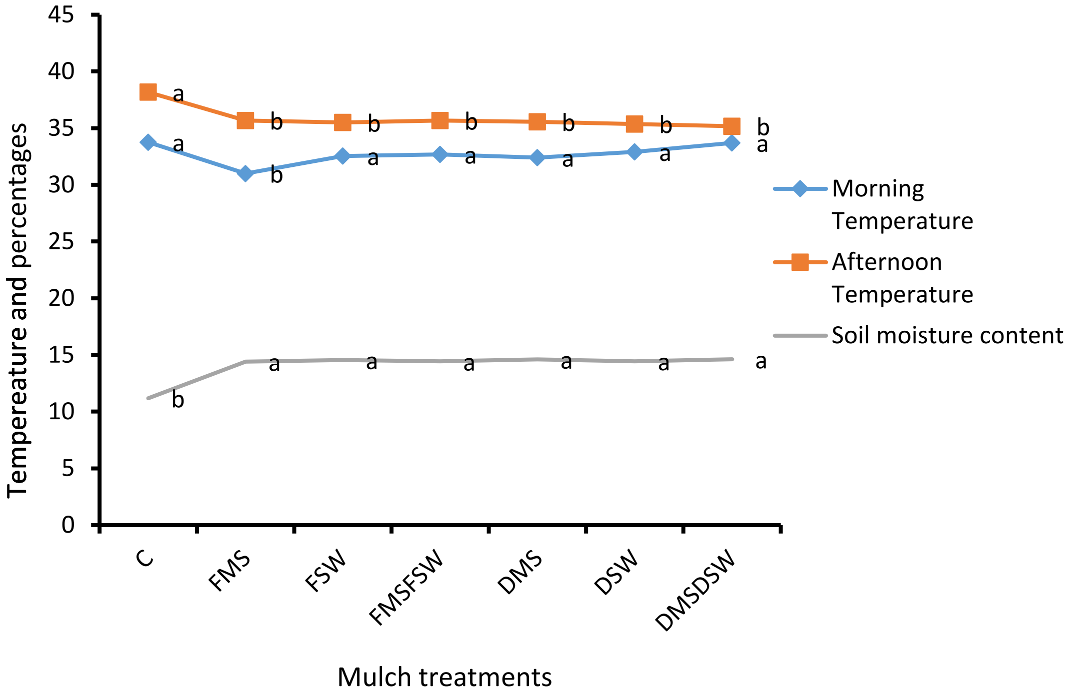


Figure 4.1: Response of banana with mulch to soil temperature and soil moisture content at 12 weeks after planting

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

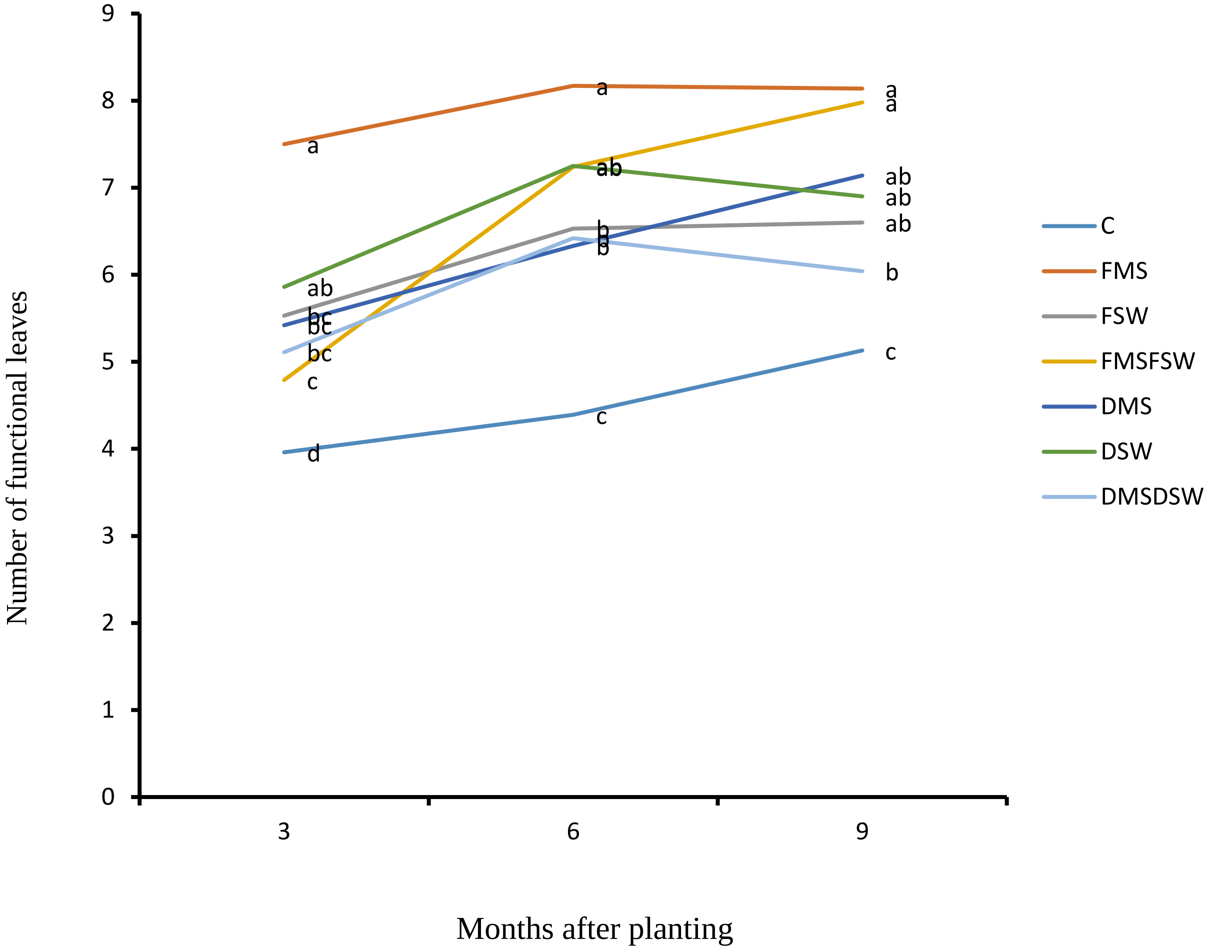


Figure 4.2. Effects of mulch on number of functional leaves of Bananas at vegetative phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control   DMS=Dried Mexican Sunflower

FMS=Fresh Mexican sunflower   DSW=Dried Siam weed and

FSW=Fresh Siam weed   DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

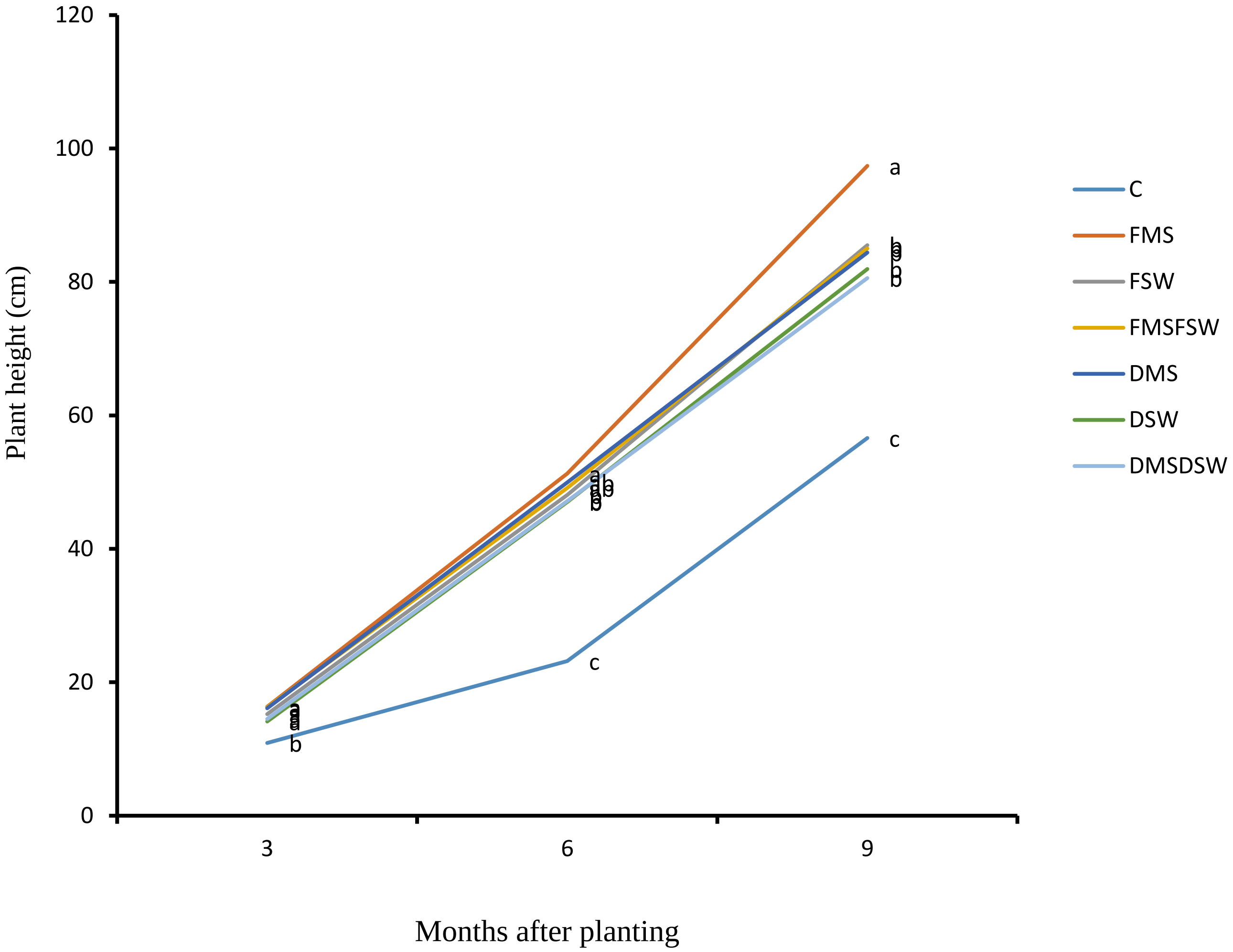


Figure 4.3. Effects of mulch on plant height (cm) of Bananas at vegetative phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control	DMS=Dried Mexican Sunflower
FMS=Fresh Mexican sunflower	DSW=Dried Siam weed and
FSW=Fresh Siam weed	DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

sunflower (DMS) (49.94 cm). The fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) produced a significantly ($p \leq 0.05$) larger leaf area than from other treatments but was not different from (FMS) fresh Mexican sunflower at 3 MAP (Figure 4.4). The treatments had no impact on the banana plants stem girth but were significantly ($p \leq 0.05$) different from the control at 3 MAP. At 6 MAP, the stem girth of banana with fresh Mexican sunflower (FMS) (3.79 cm) was significantly ($p \leq 0.05$) different from the control (C) (2.52 cm) and other treatments. Fresh Siam weed (FSW) (6.62 cm) was significantly ($p \leq 0.05$) different in stem girth from other treatments. Banana with Fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (3.33 cm) treatment had stem girth that was different significantly ($p \leq 0.05$) from the control (C) (2.52 cm), fresh Mexican sunflower (FMS) (3.79 cm) and fresh Siam weed (FSW) (2.28 cm). Also at 6 MAP, banana with fresh Mexican sunflower (FMS) performed best as mulching material over other treatments on all the parameters measured as presented in the Table 4.10.

4.4. Effects of mulch treatments on flowering phase (9-11 MAP) of banana

During flowering phase at 9 MAP, the control gave the least number of functional leaves (5.13), which was significantly ($p \leq 0.05$) different from the other treatments, while fresh Mexican sunflower (FMS) (8.14) differed significantly on dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (6.04) as presented in Figure 4.5. The highest number of functional leaves of banana with fresh Mexican sunflower (FMS) (10.14) was obtained at 11 MAP while the least number was from the control (5.23) and both different significantly ($p \leq 0.05$) from fresh Siam weed (FSW) (8.54), dried Mexican sunflower (DMS) (7.97) and dried Siam weed (DSW) (7.48). Plant height of banana with fresh Mexican sunflower (FMS) (97.40 cm) differed significantly ($p \leq 0.05$) from all other treatments at 9 MAP (figure 4.6). Banana leaf area with fresh Mexican sunflower (FMS) (612.83 cm^2) treatment was higher and significantly ($p \leq 0.05$) different from the control (C) (283.33 cm^2), fresh Siam weed (FSW) (383.83 cm^2), and all other treatments applied at 9 MAP (Figure 4.7). Table 4.11 shows that fresh Mexican sunflower (FMS) (9.31 cm) mulch on banana gave the highest mean stem girth at 9 MAP and closely followed by dried Siam weed (DSW) (8.94 cm) but not significantly different from each other at 9 MAP. The stem girth of control treatment (C) (4.57 cm) at 9 MAP has the least mean

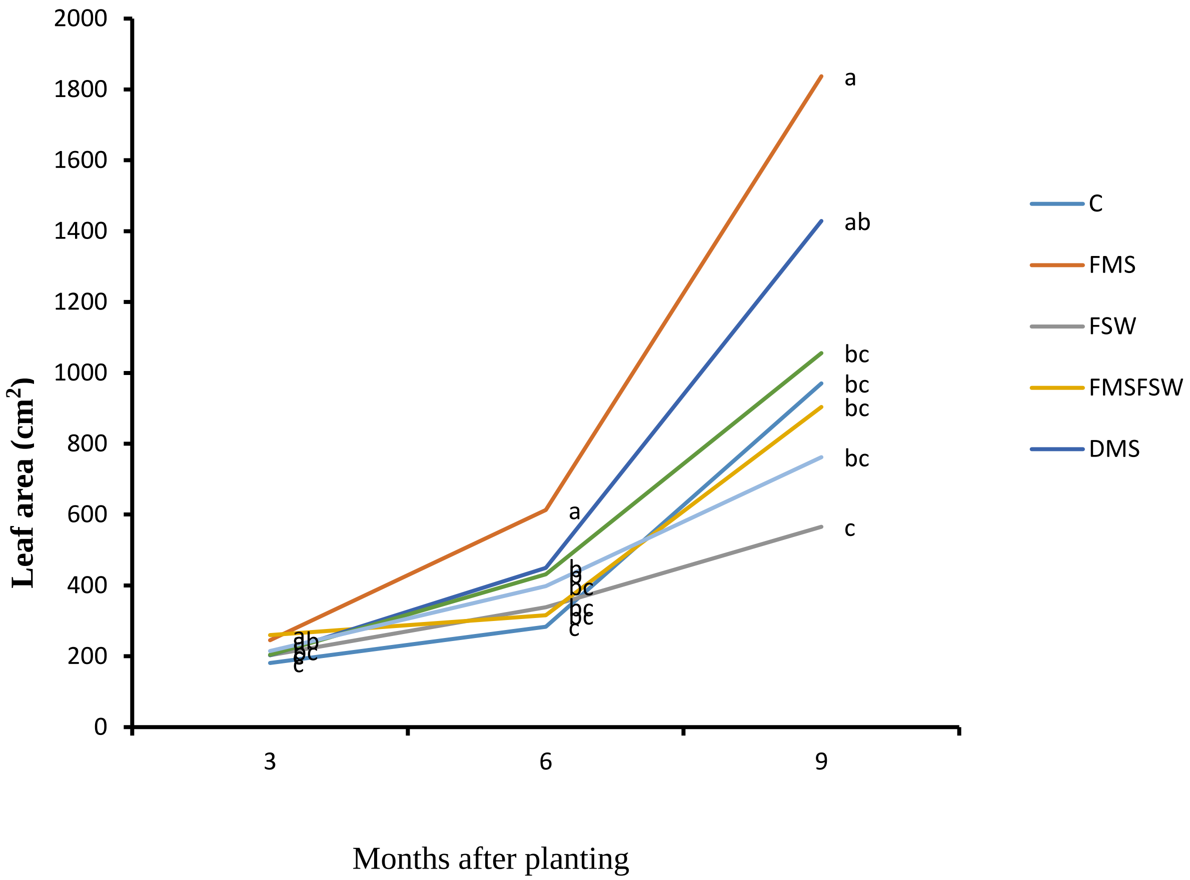


Figure 4.4. Effects of mulch on leaf area (cm^2) of Bananas at vegetative phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control	DMS=Dried Mexican Sunflower
FMS=Fresh Mexican sunflower	DSW=Dried Siam weed and
FSW=Fresh Siam weed	DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

Table 4.10. Effects of mulch on stem girth (cm) of Bananas at vegetative phase

Treatments	**Months After Planting**		
	3	**6**	**9**
C	1.79b	2.52cd	4.57d
FMS	2.37a	3.79a	9.31a
FSW	2.26a	2.28d	6.62c
FMSFSW	2.39a	3.33b	8.70ba
DMS	2.30a	2.93bc	8.15bac
DSW	2.12a	3.19b	8.94a
DMSDSW	2.25a	2.89bc	6.96bc

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

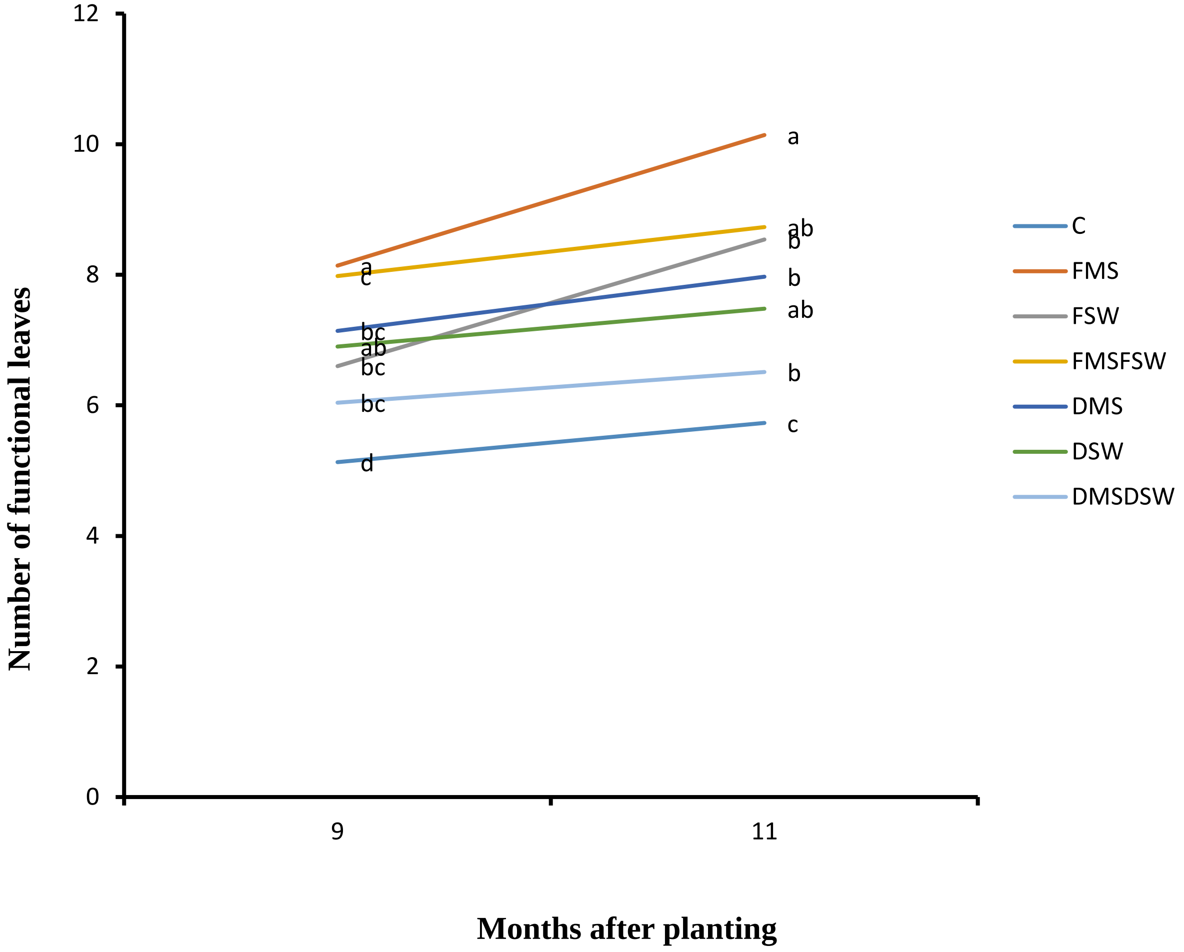


Figure 4.5. Effects of mulch on number of functional leaves of Bananas at flowering phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control

DMS=Dried Mexican Sunflower

FMS=Fresh Mexican sunflower

DSW=Dried Siam weed and

FSW=Fresh Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

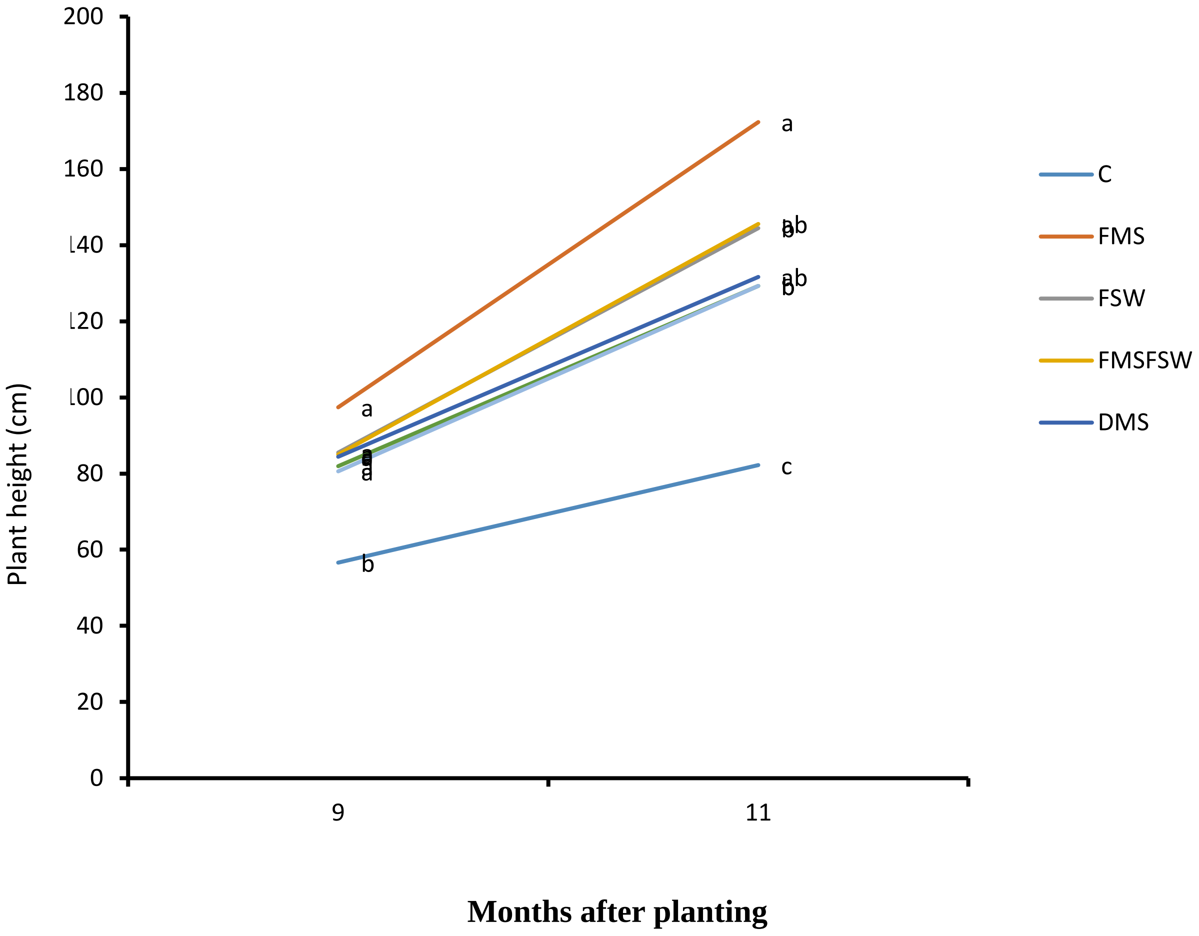


Figure 4.6. Effects of mulch on plant height (cm) of Bananas at flowering phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,	DMS=Dried Mexican Sunflower
FMS=Fresh Mexican sunflower,	DSW=Dried Siam weed
FSW=Fresh Siam weed,	DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1
FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1	

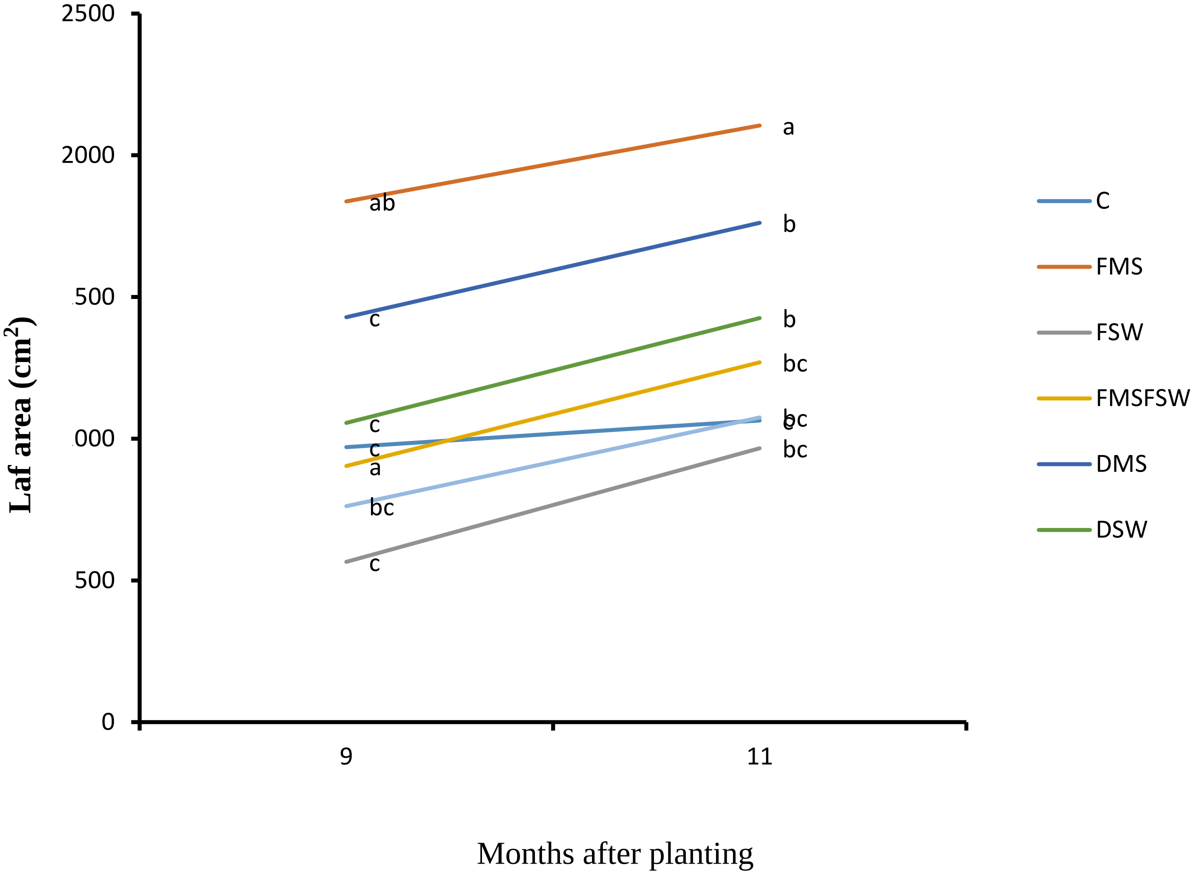


Figure 4.7. Effects of mulch on leaf area (cm^2) of Bananas at flowering phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control, DMS=Dried Mexican Sunflower

FMS=Fresh Mexican sunflower, DSW=Dried Siam weed

FSW=Fresh Siam weed, DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

Table 4.11. Effects of mulch on stem girth (cm) of Bananas at flowering phase

\Treatments	**Months After Planting**	
	9	**11**
C	4.57d	6.18c
FMS	9.31a	11.70a
FSW	6.62c	8.99b
FMSFSW	8.70ba	10.66ab
DMS	8.15bac	9.99ab
DSW	8.94a	11.23a
DMSDSW	6.96bc	10.00ab

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

value and significantly ($p \leq 0.05$) different from other the means of other treatments used in the experiment.

4.5. Effects of mulch treatments on fruiting phase (11-14 MAP) of banana

Fruiting phase till 14 MAP, banana with fresh Mexican sunflower (FMS) had the highest number of functional leaves (9.52) among the treatments used and was not significantly different from all other treatments used except the control (6.29). The number of functional leaves of banana with fresh Siam weed (FSW) (9.49) was not significantly different from fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (8.81), dried Mexican sunflower (DMS) (9.02) and dried Siam weed (DSW) (8.91) but was significantly ($p \leq 0.05$) different from dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW). The least number of functional leaves was obtained from banana in the control treatment at 14 MAP, this was also significantly ($p \leq 0.05$) different from other treatments (figure 4.8). Plant height of banana with fresh Mexican sunflower (FMS) (172.30 cm) was different significantly ($p \leq 0.05$) from plant height of banana with other treatments at 11 MAP. At 14 MAP, Plant height of banana plant with fresh Mexican sunflower (FMS) (197.5 cm) was significantly ($p \leq 0.05$) different from control (C) (108.50 cm) and also different significantly ($p \leq 0.05$) from Dried Mexican sunflower + Dried Siam weed 1:1 (DMSDSW) (151.62 cm) but not different from fresh Siam weed (FSW) (174.58 cm), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (185.41 cm), Dried Mexican sunflower (DMS) (175.19 cm) and dried Siam weed (DSW) (181.45 cm). Banana plants with fresh Mexican sunflower has the tallest plant height during the experiment's duration (figure 4.9). The largest average leaf area of banana plant was with fresh Mexican sunflower (FMS) (2105.20 cm^2) at 11 WAP while the average leaf area of banana plant with fresh Siam weed was the least (966.30 cm^2) (figure 4.10). Also at 11 MAP, Leaf area of banana with fresh Mexican sunflower (FMS) (2105.20 cm^2) was not significantly different from dried Mexican sunflower (DMS) (1761.80 cm^2). The leaf area of banana was not different among the treatments at 14 MAP. Table 4.12 shows that stem girth of banana plant with fresh Mexican sunflower treatment (11.7 cm) compared to the control (6.18 cm) treatment, was significantly ($p \leq 0.05$) different and also from banana with fresh Siam weed (8.99 cm) at 11 MAP.

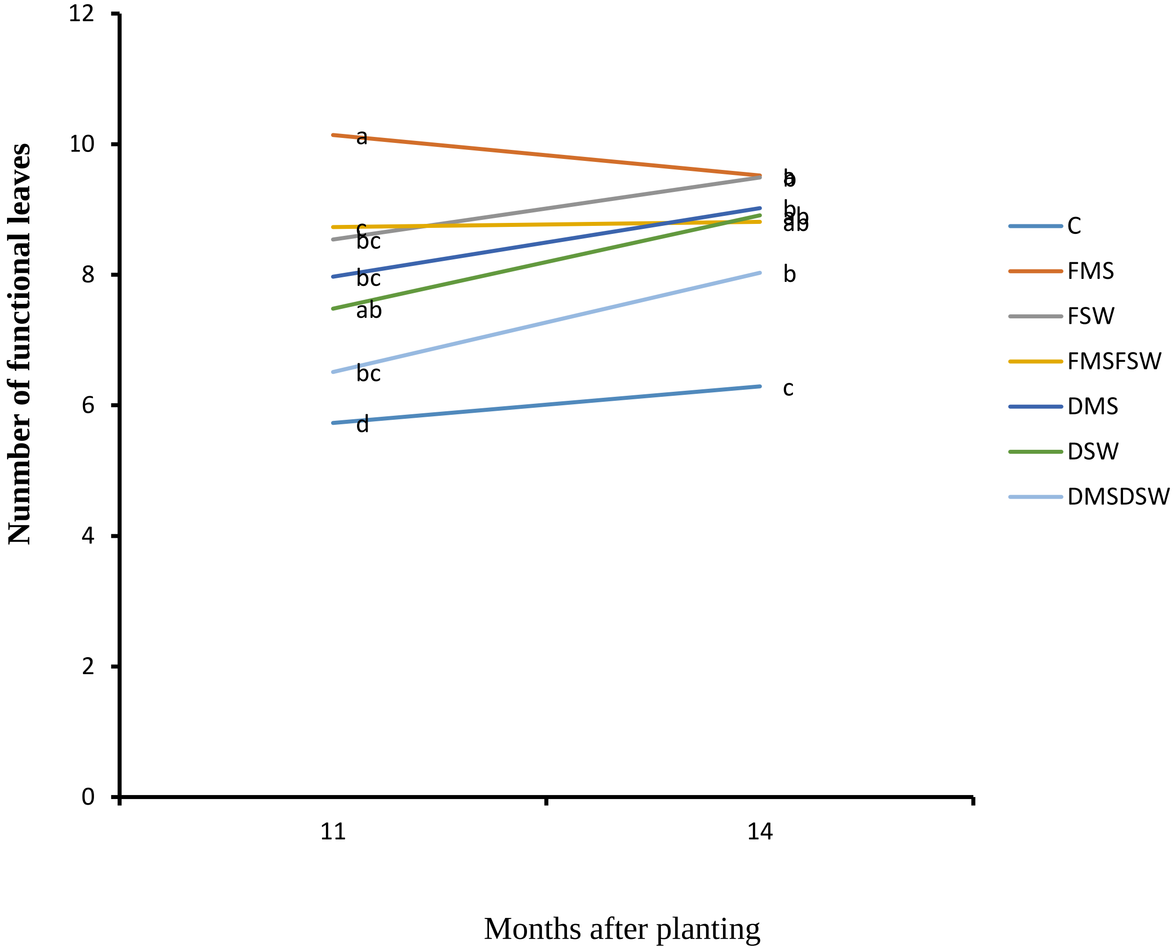


Figure 4.8. Effects of mulch on number of functional leaves of Bananas at fruiting phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control

FMS=Fresh Mexican sunflower

FSW=Fresh Siam weed

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed and

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

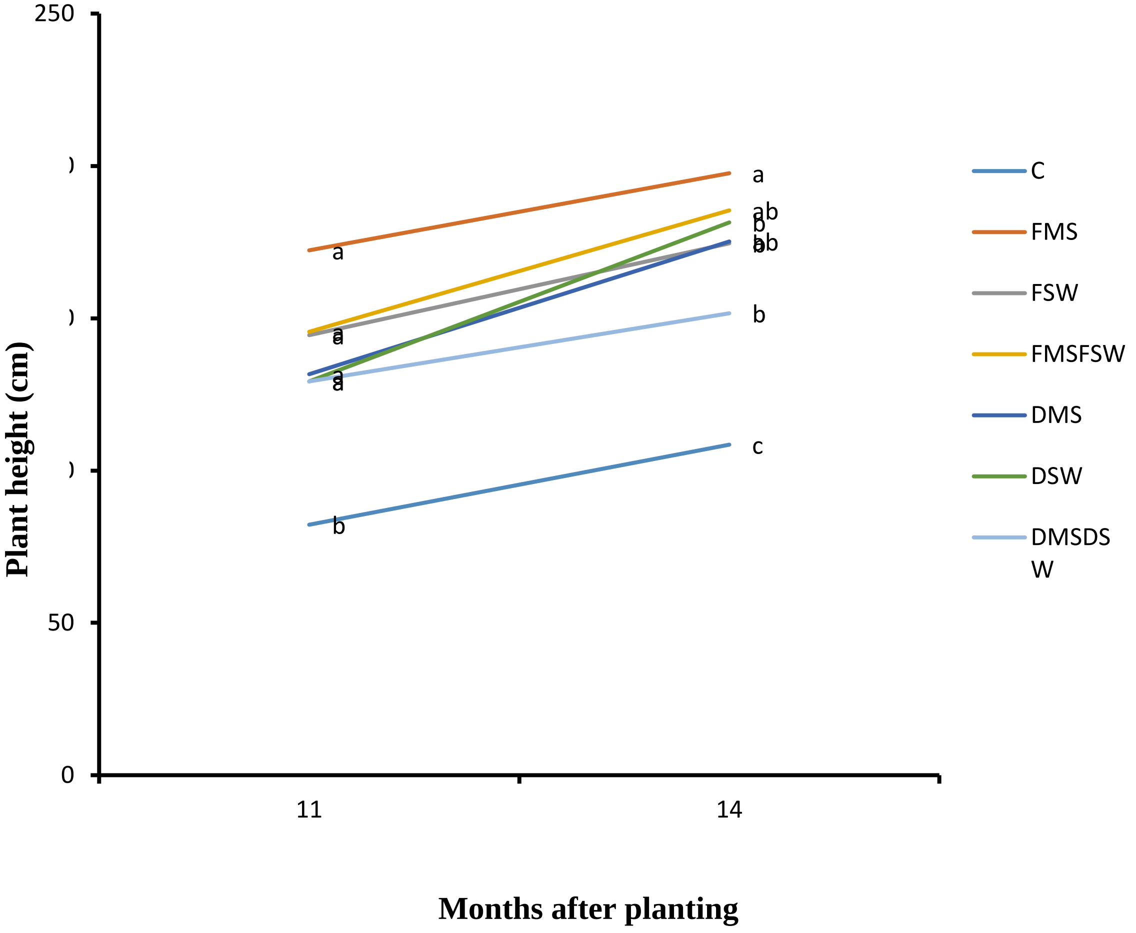


Figure 4.9. Effects of mulch on plant height (cm) of Bananas at fruiting phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = control

FMS=Fresh Mexican sunflower

FSW=Fresh Siam weed

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed and

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

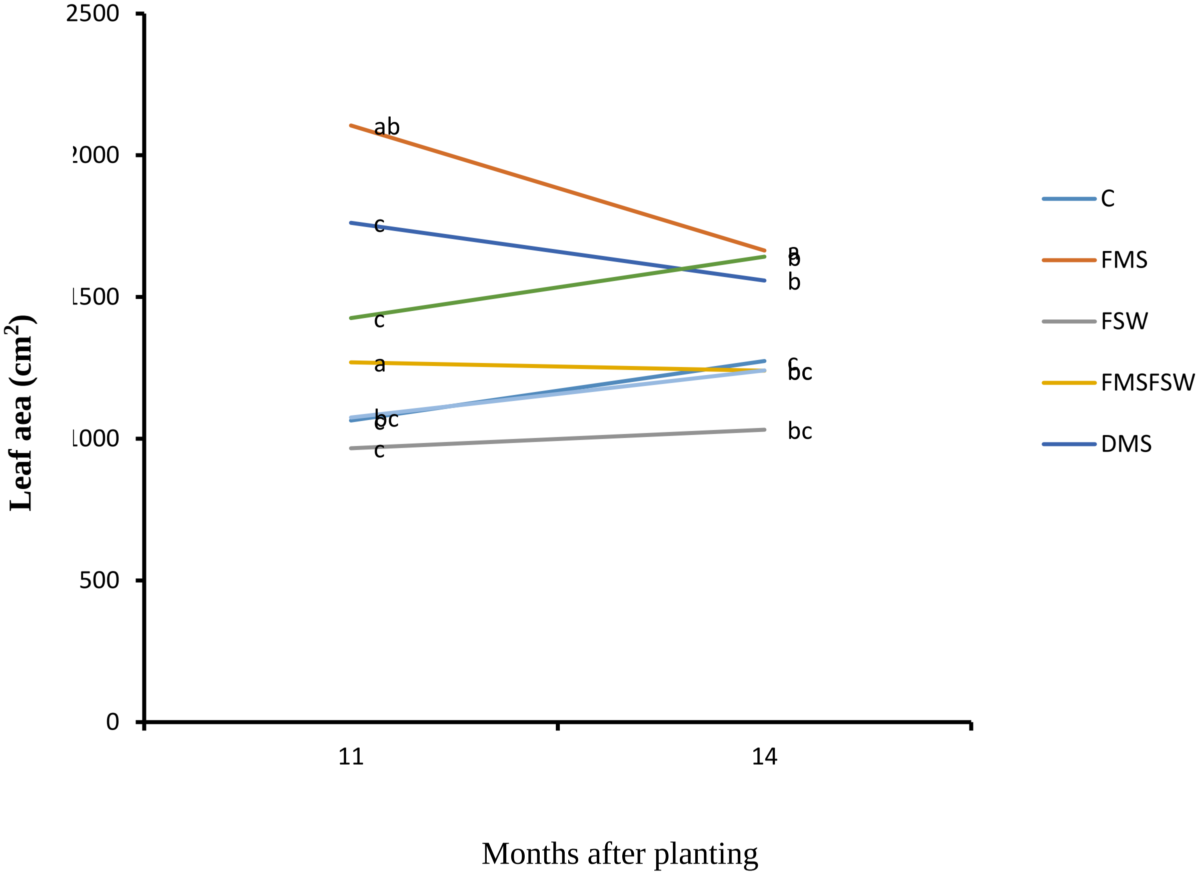


Figure 4.10. Effects of mulch on leaf area (cm^2) of Bananas at fruiting phase

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,	DMS=Dried Mexican Sunflower
FMS=Fresh Mexican sunflower,	DSW=Dried Siam weed
FSW=Fresh Siam weed,	DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1
FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1	

Table 4.12. Effects of mulch on stem girth (cm) of Bananas at fruiting phase

Treatments	**Months After Planting**	
	11	**14**
C	6.18c	7.87c
FMS	11.70a	14.25a
FSW	8.99b	11.87b
FMSFSW	10.66ab	12.26b
DMS	9.99ab	12.58ba
DSW	11.23a	12.88ba
DMSDSW	10.00ab	11.72b

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

Average stem girth of banana plant with control treatment C (7.87 cm) was significantly ($p \leq 0.05$) different from all the treatments used at 14 MAP. Average stem girth of banana plant with Fresh Mexican sunflower (FMS) (14.25 cm) was also differ significantly ($p \leq 0.05$) from average stem girth of banana with fresh Siam weed (FSW) (11.87 cm), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (12.26 cm) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (11.72 cm).

4.6. Number of suckers developed by banana

Dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) treatment developed highest average number of sucker at 11 MAP (0.88) while the least average sucker were developed by banana plants with fresh Siam weed (FMSFSW) (0.39), DMS (0.33) and control (C) (0.17) treatments. There were no significant differences in number of suckers developed by banana plants at 9 and 14 MAP as shown in Table 4.13.

4.7. Average bunch weight and number of suckers at harvest

Table 4.14 shows that the highest average bunch weight at harvest was from banana plants treated with fresh Mexican sunflower (FMS) (10.16 kg) which was not significantly different from fresh Siam weed (FSW) (10.04 kg) but both were significantly ($p \leq 0.05$) higher than the control (7.17 kg) and dried Siam weed (DSW) (9.58 kg). The least bunch weight of banana was from the control (C) treatment (7.17 kg) which was significantly ($p \leq 0.05$) lower than other treatments. Dried Siam weed (DSW) (9.58 kg) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (9.70 kg) were not significantly different from each other. The average number of suckers at harvest of banana plants with dried Mexican sunflower (DMS) was the highest (3.13) and significantly ($p \leq 0.05$) different from the control (C) (0.83), fresh Mexican sunflower (FMS) (2.50), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (2.25) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (2.63). The least average number of suckers at harvest was obtained from banana plants in the control (C) treatment (0.83) which different significantly ($p \leq 0.05$) from all other treatments. The highest sucker height at harvest was obtained from banana plants with dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (49.92 cm) which was significantly

Table 4.13. Effects of mulch on number of Banana suckers

Treatments	**Months after planting**		
	9	**11**	**14**
C	0.01a	0.17b	0.75a
FMS	0.17a	0.50ba	1.04a
FSW	0.10a	0.58ba	0.97a
FMSFSW	0.25a	0.39b	0.96a
DMS	0.01a	0.33b	1.13a
DSW	0.01a	0.58ba	1.04a
DMSDSW	0.33a	0.88a	1.83a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C= control,

FMS=Fresh Mexican sunflower,

FSW =Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

Table 4.14: Treatment effects of mulch on Banana at harvest

Treatments	Number of suckers at harvest	Highest height of sucker at harvest (cm)	Number of hands per bunch at harvest	Bunch Weight at harvest (kg)
C	0.83d	35.97b	6.43c	7.17d
FMS	2.50bc	39.15ba	12.12a	10.16a
FSW	2.88ba	38.53ba	11.22a	10.04a
FMSFSW	2.25c	42.05ba	11.07ba	9.88bac
DMS	3.13a	46.55ba	11.28ba	9.96ba
DSW	2.92ba	46.62ba	10.32b	9.58c
DMSDSW	2.63bc	49.92a	11.07ba	9.70bc

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C= control,

FMS=Fresh Mexican sunflower,

FSW=Fresh Siam weed,

FMSFSW=Fresh Mexican sunflower + Fresh Siam weed 1:1

DMS=Dried Mexican Sunflower

DSW=Dried Siam weed

DMSDSW=Dried Mexican sunflower + Dried Siam weed 1:1

($p \leq 0.05$) different from the control (C) (35.97 cm) and different from other treatments. The height of the tallest sucker in fresh Mexican sunflower (FMS) (39.15 cm), fresh Siam weed (FSW) (38.53 cm), fresh Mexican sunflower + fresh Siam weed 1:1 (FMSFSW) (38.53 cm), dried Mexican sunflower (DMS) (46.55 cm), dried Siam weed (DSW) (46.62 cm) and dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW) (49.92 cm) were not significantly different from each other.

4.8. Nutrients composition of formulated composts- Incubation study

Table 4.15 shows that Cassava peel + Siam weed + Mexican sunflower compost ($C_PS_WM_S$) has the highest total nitrogen (38.53 g/kg) which is almost twice the value of other compost materials and also the highest amount of available potassium (26.13 g/kg). Cassava peel (C_P) has the least values of total nitrogen (4.2 g/kg), total phosphorus (1.12 g/kg), magnesium (0.02 g/kg), calcium (1.2 g/kg) and available potassium (7.31 g/kg).. Cassava peel +Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) has the highest calcium (14.03 g/kg) among other composts analyzed and second in total Nitrogen content (18.25 g/kg).

4.9. Nutrient determined pattern of the formulated composts

Total nitrogen determined at 2 WAI was highest with $C_PP_MS_WM_S$ (2.30 g/kg) followed in decreasing order by C_PP_M (2.02 g/kg), C_PM_S(1.86 g/kg), $C_PS_WM_S$ (1.37 g/kg), C_PS_W (1.12 g/kg) and least in control (0.94 g/kg). At 6 WAI the least value of total N determined was (0.46 g/kg) in control while the highest was (1.12 g/kg) in C_PP_M. The least value of Nitrogen release to sand at 8 WAI (0.37 g/kg) was obtained from $C_PP_MS_WM_S$ and control (0.34 g/kg). Highest value of total Nitrogen was determined from C_PP_M at 6, and 10 WAI which was significantly higher than all other composts. From figure 4.11, there were increases in total Nitrogen determined by $C_PP_MS_WM_S$, C_P, $C_PS_WM_S$ and C_PP_M on washed sand at 10 WAI compared to the value determined at 8 WAI. Compost $C_PP_MS_WM_S$ increased the value of Nitrogen to sand by 97.01% from 8 WAI to 10 WAI. The release pattern of nitrogen by the composts at all the stages of incubation are shown in Figure 4.6. At 2 WAI, total P was highest with cassava peel + poultry manure (C_PP_M) (82.56 mg /kg) greater than C_PM_S by 68.8 % and control (C) by 412.5 % which was washed river

Table 4.15. Nutrient composition (g/kg) of composts used for experiments 2 and 3

Treatments	Total Nitrogen	Total Phosphorus	Ca	Mg	K
C_P	4.20d	1.12c	1.20c	0.02c	7.31c
C_PP_M	16.67b	2.67b	4.47b	0.35a	8.95bc
C_PS_W	5.13c	1.65c	1.56c	0.03c	8.68bc
C_PM_S	5.51c	1.34c	2.41d	0.06c	8.61bc
$C_PP_MS_WM_S$	16.74b	3.86a	8.25a	0.23b	11.93b
$C_PS_WM_S$	38.53a	2.75b	3.11c	0.38a	26.13a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W=Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel+ Siam weed + Mexican sunflower.

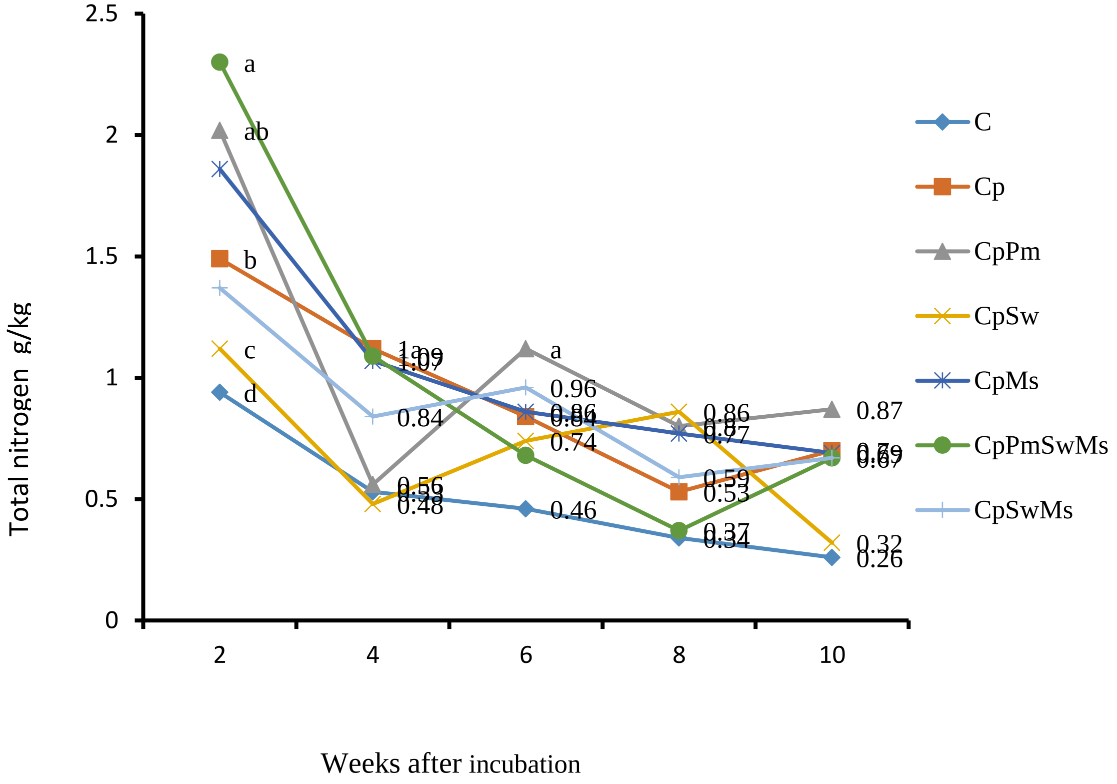


Figure 4.11. Total Nitrogen determined of compost treatments by weeks of incubation

C = Control (No compost), CP = Cassava peel, CPPM = Cassava peel + Poultry manure, CPSW= Cassava peel + Siam weed, CPMS = Cassava peel + Mexican sunflower, CPPMSWMS =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and CPSWMS = Cassava peel + Siam weed + Mexican sunflower.

sand. The total phosphorus determined from C, C_P and C_PP_M at 4 WAI dropped compared to 2 WAI while the values increased in other composts. The Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost ($C_PP_MS_WM_S$) determined significantly more phosphorus to sand than all other composts over 10 weeks of the incubation period being 80.80 mg /kg, 129 mg /kg, 118.75 mg /kg and 115.03 mg /kg at 4, 6, 8 and 10 WAI respectively. The exchangeable potassium determined by cassava peel + poultry manure + Siam weed + Mexican sunflower $C_PP_MS_WM_S$ was the highest (1.91 cmol/kg) at 2 WAI. The exchangeable Potassium determined by Cassava peel (C_PS_W) was the highest at 4 WAI (1.46 cmol/kg) closely followed by $C_PS_WM_S$ with (1.28cmol/kg) and both were higher than other treatments while the least values were obtained from Cassava peel (C_PP_M) (0.34 cmol/kg) and Cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) composts (figure 4.12). Also at 6 WAI, cassava peel+ Mexican sunflower C_PM_S determined the highest value of exchangeable potassium (1.38 cmol/kg) (figure 4.13). Potassium determined by $C_PS_WM_S$ and C_P decreased (1.22 cmol/kg) and (0.74 cmol/kg) to (1.18 cmol/kg) and (0.72cmol/kg) as weeks of incubation increases from 6 to 8 WAI respectively.

Table 4.16 shows C_PP_M (13.17 cmol/kg) determined the highest calcium at 2 WAI closely followed by $C_PP_MS_WM_S$ (12.38 cmol/kg) and $C_PS_WM_S$ (11.45 cmol/kg) composts. The values of calcium determined by all the treatments were more than values of control (2.62 cmol/kg) by more than 200 % at 2 WAI. $C_PS_WM_S$ determined highest value of Ca at 8 (10.45 cmol/kg) and at 10 WAI (10.93 cmol/kg). The highest magnesium value determined to soil was from C_PP_M at 2 (2.65 cmol/kg), (7.65 cmol/kg) at 4 and (1.77 cmol/kg) at 10 WAI as shown in Table 4.17. More concentrations of calcium than potassium and magnesium were determined by all the composts at 2, 4 and 6 WAI (Figures 4.14, 4.15 and 4.16). The least value of potassium (0.61 cmol/kg), (0.33 cmol/kg), (0.48 cmol/kg) and (0.48 cmol/kg) were determined respectively at 2, 6, 8 and 10 WAI which were higher and significantly ($p \leq 0.05$) different from the control (Figures 4.17 and 4.18). The concentration of Calcium determined were almost triple of potassium and double that of magnesium nutrients especially in C_PP_M, $C_PS_WM_S$, C_PS_W and C_PM_S.

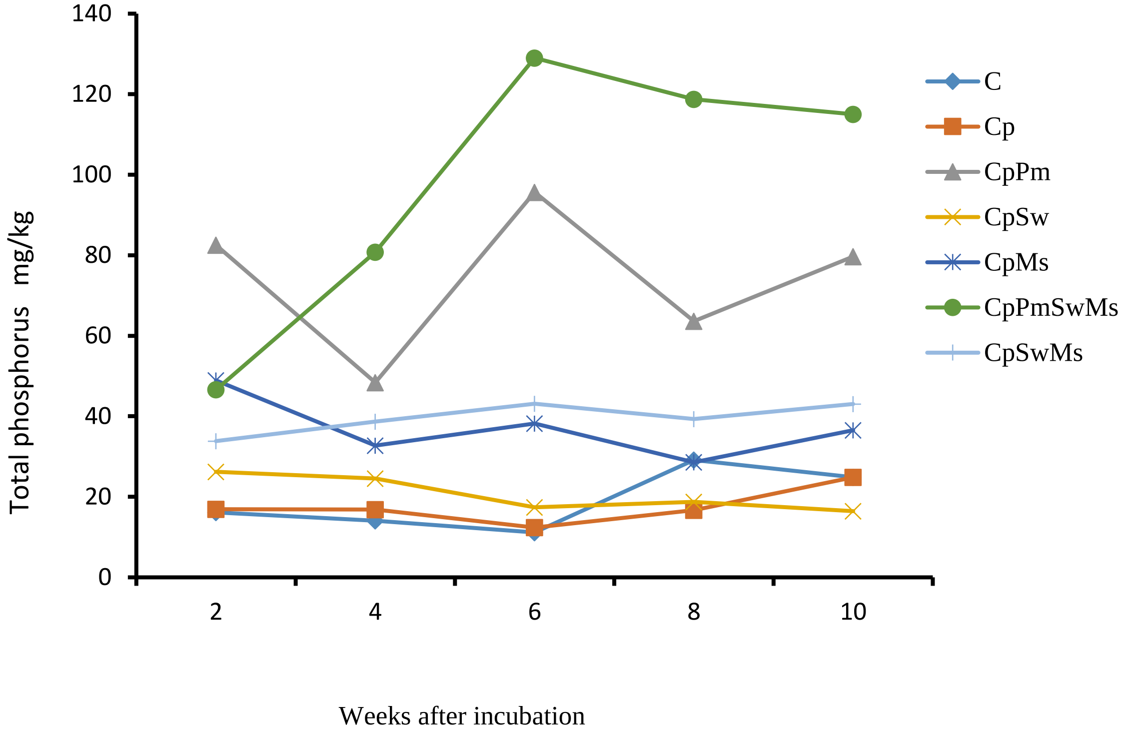


Figure 4.12. Total Phosphorus determined of compost treatments by weeks of incubation

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

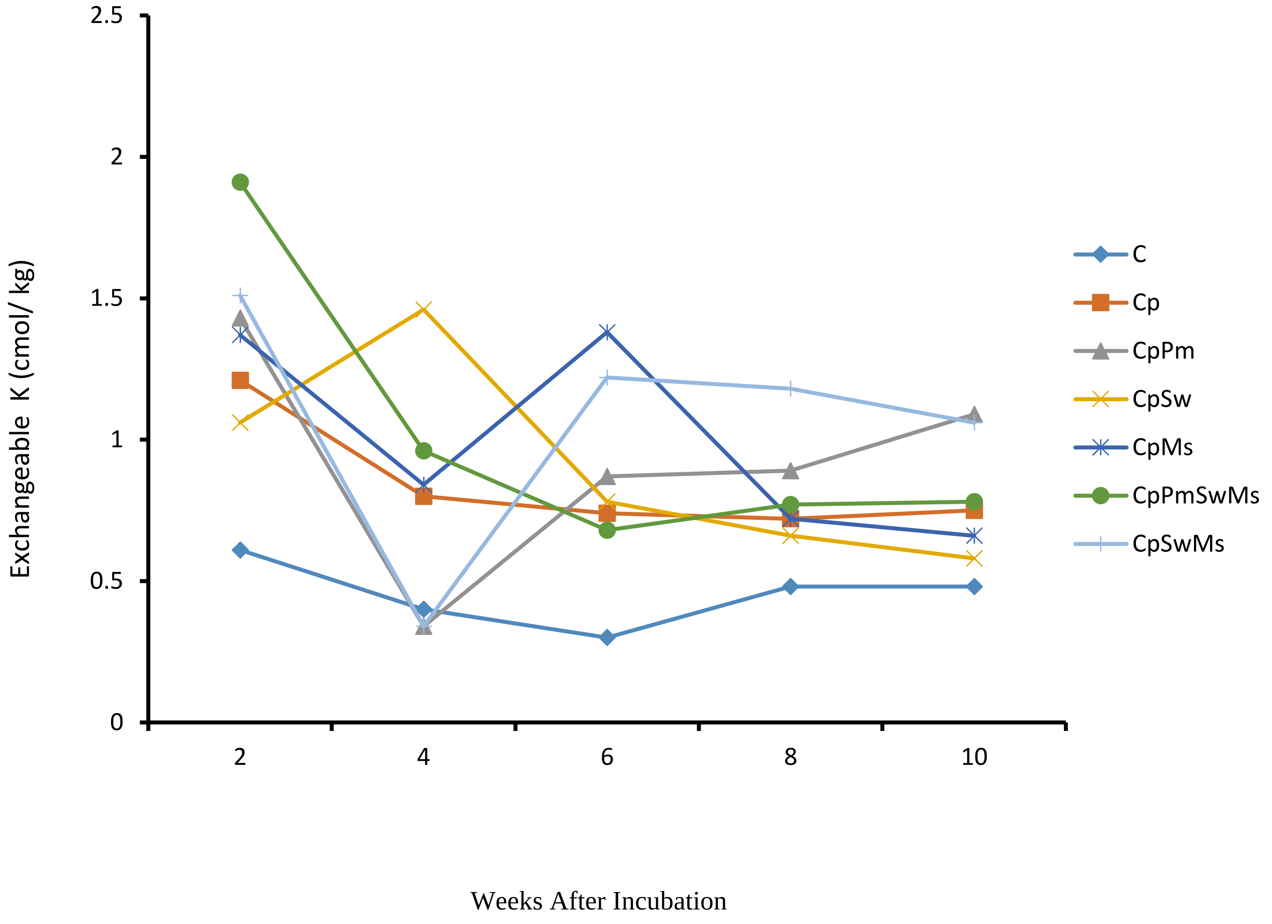


Figure 4.13. Exchangeable Potassium (cmol /kg) determined of compost treatments by weeks of incubation

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower.

Table 4.16. Exchangeable Calcium (cmol/kg) determined from compost treatments on washed river sand

Treatment	Weeks after incubation				
	2	4	6	8	10
C	2.62e	2.54c	2.88c	4.48bc	4.43b
C_P	7.43c	9.43b	9.67a	4.14bc	3.45bc
C_PP_M	13.17a	23.05a	3.64c	4.64bc	4.95b
C_PS_W	4.51d	5.42c	6.01b	3.14c	2.11c
C_PM_S	6.48cd	8.72b	5.34b	3.48c	3.10bc
$C_PP_MS_WM_S$	12.38ab	21.08a	2.32c	5.16b	3.74bc
$C_PS_WM_S$	11.45b	23.40a	1.76d	10.45a	10.93a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower.

Table 4.17. Exchangeable Magnesium (cmol/kg) determined from compost treatments on washed river sand

Treatment	Weeks after incubation				
	2	4	6	8	10
C	0.84bc	1.03c	0.62b	1.98ab	1.68a
C_P	1.56b	1.96c	1.35a	1.58ab	1.11ab
C_PP_M	2.65a	7.65a	0.67b	2.37a	1.77a
C_PS_W	0.42c	0.61c	0.62b	0.81b	0.52b
C_PM_S	0.94bc	0.73c	0.81ab	0.70b	0.64b
$C_PP_MS_WM_S$	2.43a	4.93b	0.42b	2.72a	1.31a
$C_PS_WM_S$	1.99a	5.47b	0.34b	1.07ab	1.14ab

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel+ Siam weed + Mexican sunflower.

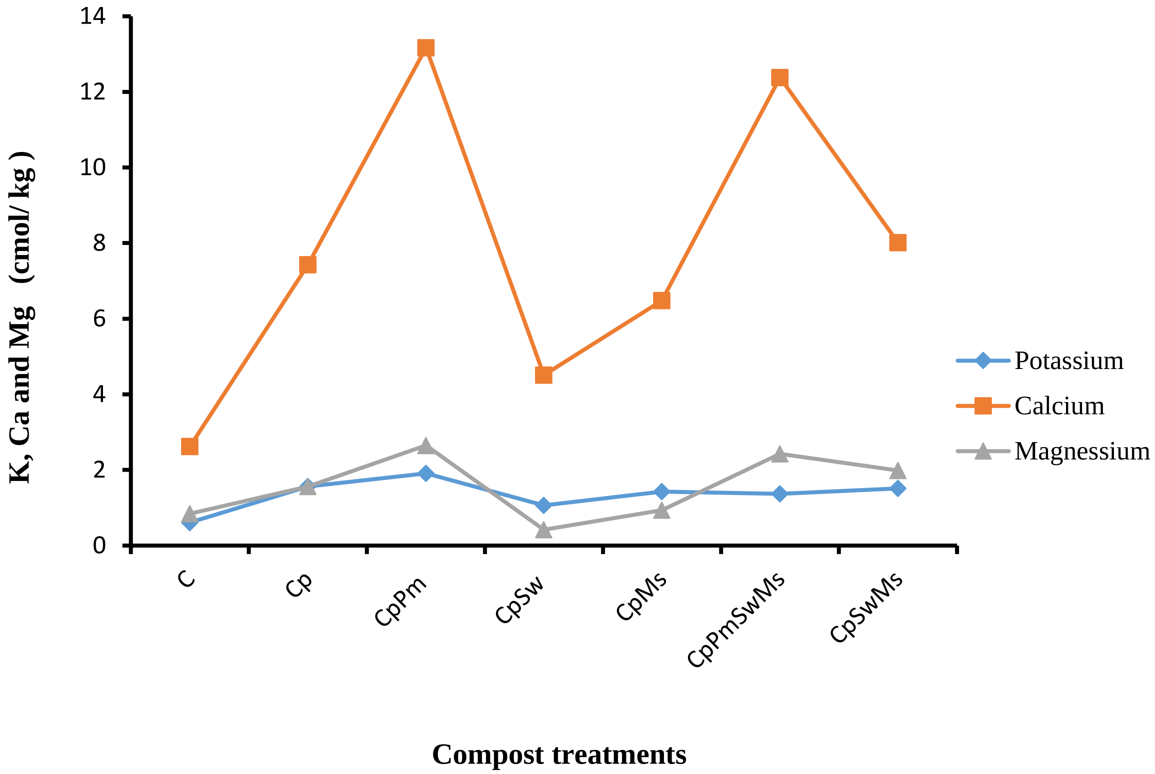


Figure 4.14. Potassium, Calcium and Magnesium determined at 2weeks after incubation

C = Control (No compost), CP = Cassava peel, CPPM = Cassava peel + Poultry manure, CPSW= Cassava peel + Siam weed, CPMS = Cassava peel + Mexican sunflower, CPPMSWMS =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and CPSWMS = Cassava peel + Siam weed + Mexican sunflower.

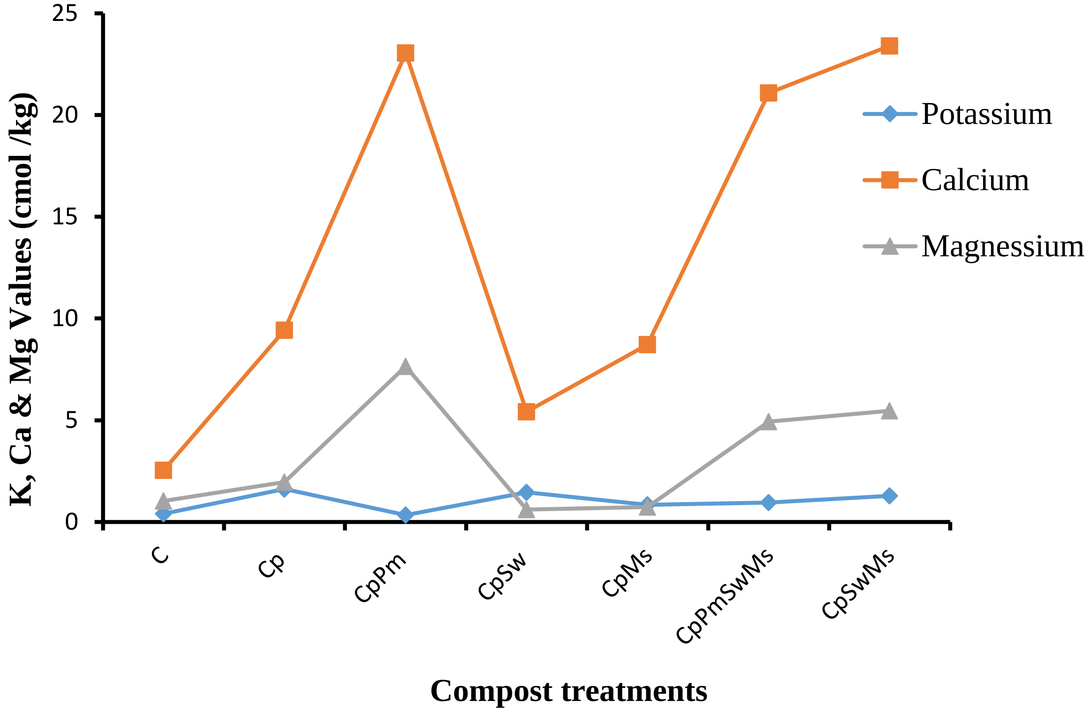


Figure 4.15. Potassium, Calcium and Magnesium determined at 4weeks after incubation WAI

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower.

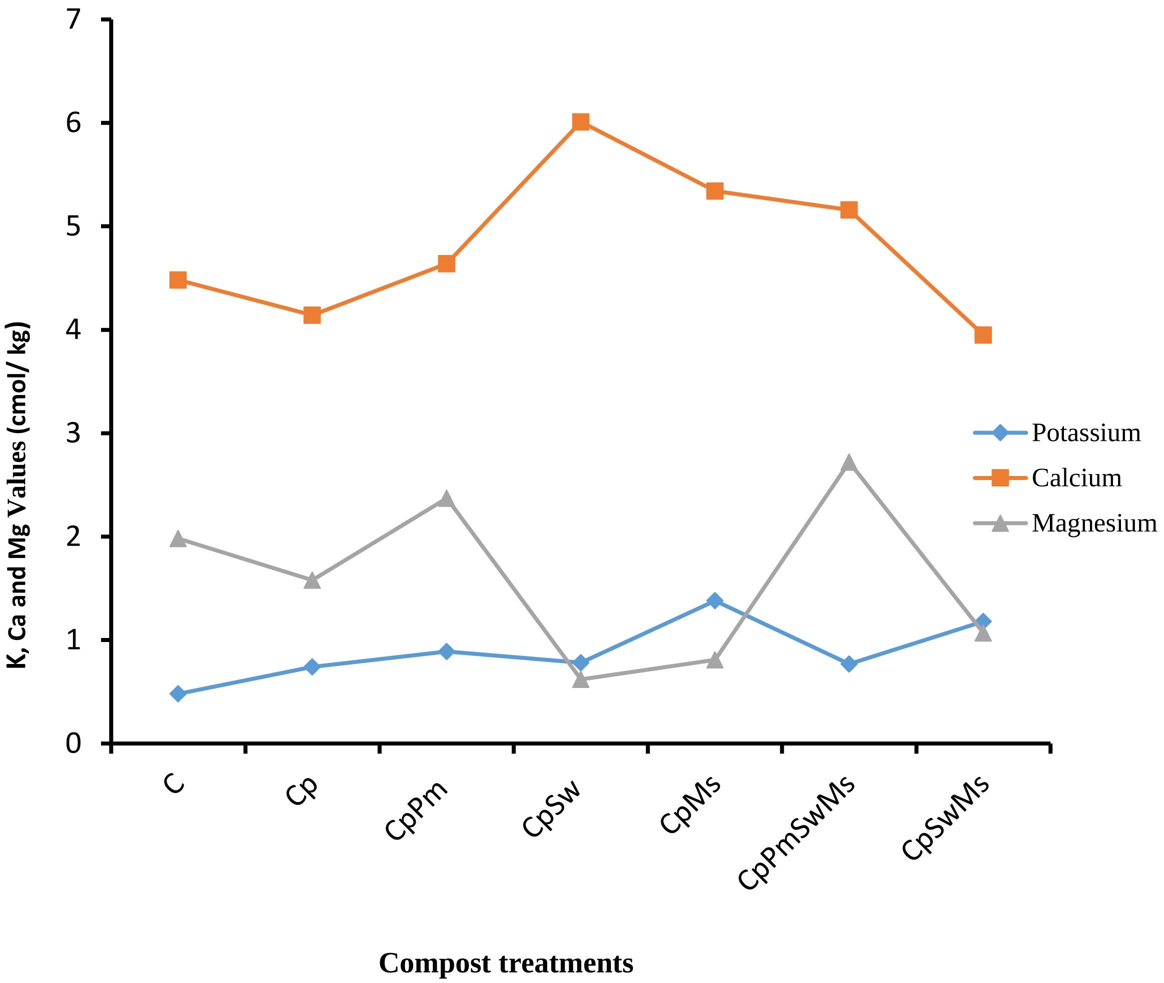


Figure 4.16. Potassium, Calcium and Magnesium determined at 6weeks after incubation

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower.

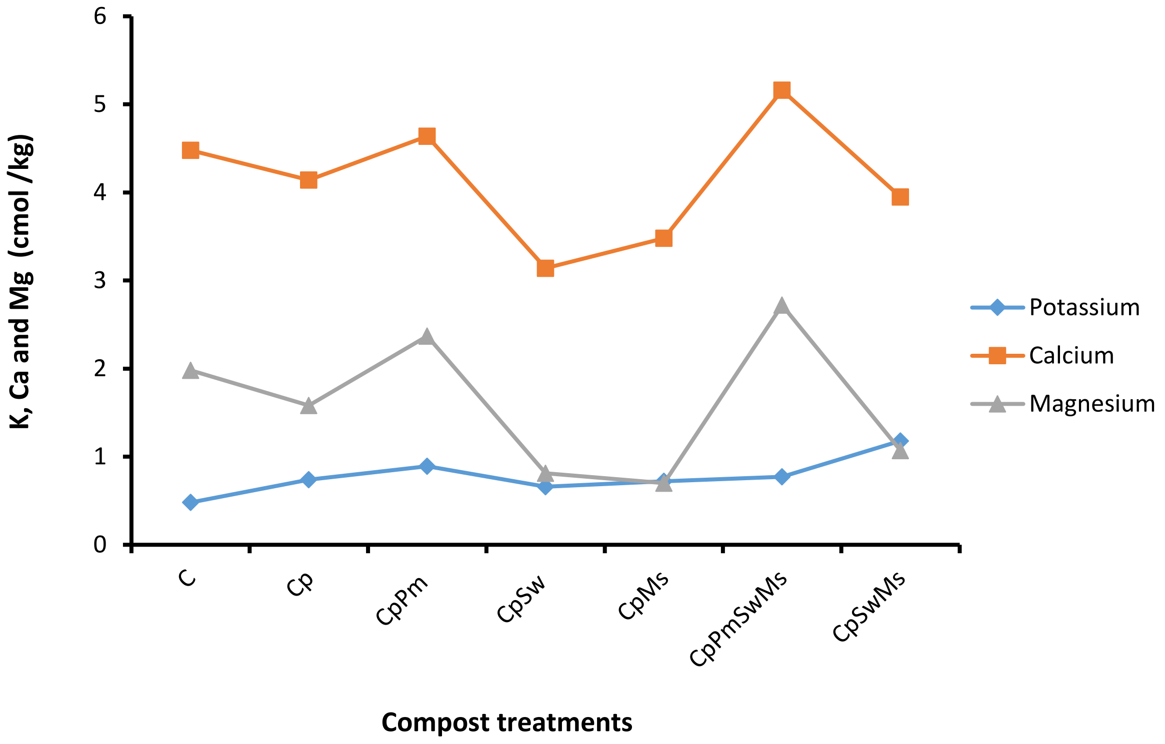


Figure 4.17. Potassium, Calcium and Magnesium release at 8weeks after incubation

C = Control (No compost), C_P = Cassava peel, C_PP_M = Cassava peel + Poultry manure, C_PS_W= Cassava peel + Siam weed, C_PM_S = Cassava peel + Mexican sunflower, $C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and $C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower.

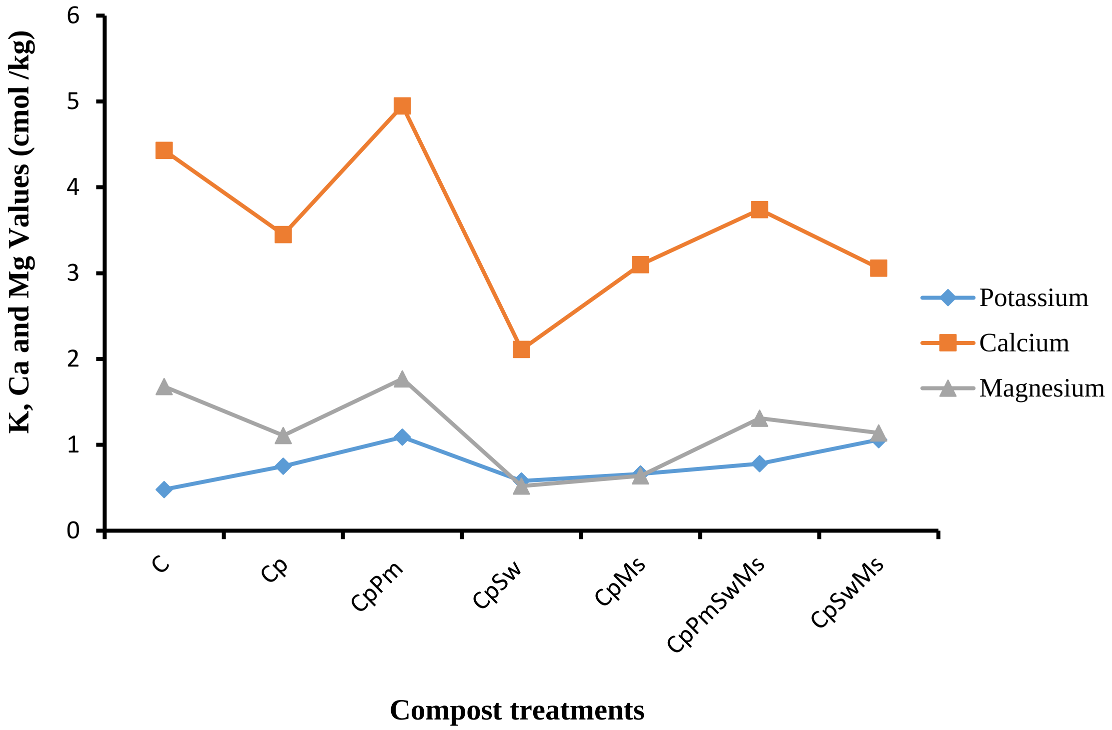


Figure 4.18. Potassium, Calcium and Magnesium determined at 10 weeks after incubation

C = Control (No compost), CP = Cassava peel, CPPM = Cassava peel + Poultry manure, CPSW= Cassava peel + Siam weed, CPMS = Cassava peel + Mexican sunflower, CPPMSWMS =Cassava peel + Poultry manure + Siam weed + Mexican sunflower and CPSWMS = Cassava peel + Siam weed + Mexican sunflower.

4.10. Effects of formulated composts on vegetative growth of Large Banana

The banana plants given with compost poultry manure + Siam weed + Mexican sunflower ($C_PS_WM_S$) has the highest average number of functional leaves (8.93) which was significantly ($p \leq 0.05$) different from cassava peel + poultry manure (C_PP_M) (5.87) at 3 MAP. At 6 MAP, the least average number of functional leaves of banana from cassava peel + poultry manure (C_PP_M) treatment (8.00) was significantly ($p \leq 0.05$) different from other compost treatments.

4.11. Effects of Formulated composts on banana at vegetative phase (2-8 MAP)

There was no significant difference found in number of functional leaves among the treatments on banana at both 3 and 6 MAP (Table 4.18). The banana with Cassava peel+ Siam weed + Mexican sunflower ($C_PS_WM_S$) was lower and significantly ($p \leq 0.05$) different in number of functional leaves from Cassava peel+ poultry manure at 3 MAP, banana with Cassava peel+ Siam weed + Mexican sunflower ($C_PS_WM_S$) gave the lowest and significantly ($p \leq 0.05$) different from other composts in number of functional leaves. In table 4.19, plant height of banana with Cassava peel+ Siam weed + Mexican sunflower ($C_PS_WM_S$) gave the highest and significantly ($p \leq 0.05$) different value at 3 and 6 MAP. Leaf area of banana plants with Cassava peel+ Siam weed + Mexican sunflower ($C_PS_WM_S$) was significantly ($p \leq 0.05$) different from other composts and the control (Table 4.20). There were no significant differences among all the composts in leaf area except banana plant with Cassava peel + Siam weed + Mexican sunflower $C_PS_WM_S$ which gave significantly ($p \leq 0.05$) higher leaf areas (1870.7 m^2) and (2612.0 m^2) at 3 and 6 MAP respectively. There were no significant differences in stem girth of banana plants with all the treatments at 3 MAP (Table 4.21). Stem girths of banana plants with Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) (7.10 cm) was not different significantly from stem girth of banana plants with Cassava peel + Mexican sunflower + Siam weed ($C_PS_WM_S$) (7.31 cm) but were higher and significantly ($p \leq 0.05$) different from other treatments including the control at 6 MAP.

Table 4.18. Effects of composts on number of functional leaves of large banana at vegetative phase

Treatments	**Months after planting**		
	3	**6**	**9**
C	7.63ab	10.60a	10.77ba
C_PP_M	5.87b	8.00b	11.73ba
$C_PP_MS_WM_S$	6.33ab	11.20a	12.20a
$C_PS_WM_S$	8.93a	11.80a	10.13c

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.19. Effects of composts on plant height (cm) of large banana at vegetative phase

Treatments	Months after planting		
	3	**6**	**9**
C	18.00b	64.29b	84.41b
C_PP_M	19.55b	65.05b	82.13b
$C_PP_MS_WM_S$	19.40b	66.13b	99.83b
$C_PS_WM_S$	28.49a	77.44a	119.26a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.20. Effects of composts on leaf area (cm^2) of large banana at vegetative phase

Treatments	Months after planting		
	3	6	9
C	132.0b	468.8b	648c
C_PP_M	258.3b	594.3b	1048b
$C_PP_MS_WM_S$	437.5b	623.8b	4746a
$C_PS_WM_S$	1870.7a	2612.0a	731c

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower

Table 4.21. Effects of composts on stem girth (cm) of large banana at vegetative phase

Treatments	**Months after planting**		
	3	**6**	**9**
C	2.36a	4.62d	7.54c
C_PP_M	2.79a	6.52bc	9.04b
$C_PP_MS_WM_S$	2.45a	7.10ab	10.10a
$C_PS_WM_S$	2.38a	7.31a	10.32a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

4.12. Effects of formulated composts on banana at flowering phase (9-11 MAP)

At 9 MAP, banana plants with cassava peel + poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) had the highest average number of functional leaves (12.20) which was significantly ($p \leq 0.05$) different from cassava peel + Mexican sunflower + Siam weed ($C_PS_WM_S$) (10.13). There were no significance ($p \geq 0.05$) differences in number of functional leaves of banana plants with all the treatments at 12 MAP (Table 4.22). In Table 4.23, the banana grown with Cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) was the tallest (28.49 cm) and significantly ($p \leq 0.05$) different from other composts applied including the control at 9 and 12 MAP. The height of banana plants with control (C) (112.62 cm) was the least and significantly ($p \leq 0.05$) different from other composts at 12 MAP. Leaf area of banana plants with all the composts applied showed no significance ($P \geq 0.05$) difference among each other except Cassava peel + Mexican sunflower + Siam weed ($C_PM_SS_W$) which was significantly ($p \leq 0.05$) different from other composts applied at all the periods of study. Cassava peel + poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) gave the highest LA which was significantly ($p \leq 0.05$) different from leaf areas of banana plants of other treatments used at 9 and 12 MAP with 4746.0 m^2 and 7103.7 m^2 respectively (Table 4.24). There was no significant difference in stem girth of banana with Cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) (10.32 cm) and banana with cassava peel + poultry manure +Mexican sunflower + Siam weed ($C_PP_MS_WM_S$) (10.10 cm) but the values were higher and significantly ($p \leq 0.05$) different from the control (C) (7.54 cm) and cassava peel + Poultry manure (C_PP_M) (9.04 cm) composts at 9 MAP. From table 4.25, stem girth of banana plant with control (C) compost (9.66 cm) at 12 MAP, was the least and was significantly ($p \leq 0.05$) different from stem girth of banana plants of other composts applied. Also at 12 MAP, stem girth of banana plants with cassava peel + Poultry manure + Siam weed + Mexican Sunflower ($C_PP_MS_WM_S$) (14.29 cm) was not significantly different from average stem girth of banana plants with cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) (13.22 cm).

Table 4.22. Effects of composts on number of functional leaves of large banana at flowering phase

Treatments	**Months after planting**	
	9	**12**
C	10.77ba	10.33a
C_PP_M	11.73ba	11.07a
$C_PP_MS_WM_S$	12.20a	11.00a
$C_PS_WM_S$	10.13c	11.07a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.23. Effects of composts on plant height (cm) of large banana at flowering phase

Treatments	Months after planting	
	9	**12**
C	84.41b	112.62c
C_PP_M	82.13b	134.78dc
$C_PP_MS_WM_S$	99.83b	159.61b
$C_PS_WM_S$	119.26a	175.49a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.24. Effects of composts on leaf area (cm^2) of large banana at flowering phase

Treatments	Months after planting	
	9	**12**
C	648c	850.2c
C_PP_M	1048b	2037.1b
$C_PP_MS_WM_S$	4746a	7103.7a
$C_PS_WM_S$	731c	1431.1bc

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.25. Effects of composts on stem girth (cm) of large banana at flowering phase

Treatments	Months after planting	
	9	12
C	7.54c	9.66b
C_PP_M	9.04b	13.00ab
$C_PP_MS_WM_S$	10.10a	14.29a
$C_PS_WM_S$	10.32a	13.22ab

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower

4.13. Effects of Formulated composts on banana at fruiting phase (11-14 MAP)

There were no significant difference in number of functional leaves of banana treated with all the composts at 12 and 14 MAP (Table 4.26). Tallest banana was obtained from banana plant with cassava peel + Siam weed + Mexican Sunflower ($C_PS_WM_S$) which was significantly different from other composts at both 12 and 14 MAP with 175.49 cm and 179.24 cm respectively as shown in table 4.27. The height was followed by banana treated with cassava peel + Poultry manure + Siam weed + Mexican Sunflower ($C_PP_MS_WM_S$) with 159.61 cm and 160.42 cm respectively at 12 and 14 MAP.

Table 4.28 shows banana with cassava peel + Poultry manure + Siam weed + Mexican Sunflower ($C_PP_MS_WM_S$) having highest leaf area significantly different from other composts with 7103.7 cm^2 and 7158.4 cm^2 respectively at 12 and 14 MAP. The least value of leaf area was obtained from the control at both 12 and 14 MAP which was significantly different from other banana treated with other composts. On stem girth of banana at fruiting phase, banana with cassava peel + Poultry manure + Siam weed + Mexican Sunflower ($C_PP_MS_WM_S$) had the highest but not significantly different from other composts except the control at 12 and 14 MAP (Table 4.29).

In table 4.30, the number of suckers developed was highest in banana plants with poultry manure + Mexican sunflower + Siam weed ($C_PP_MS_WM_S$) (3.00) and significantly ($p \leq 0.05$) different from banana plants with other treatments at 6 MAP. The least number of sucker was obtained from banana plants with cassava peel (C_PP_M) (0.20) which was not significantly different from the control (C) (0.07) and not significantly different from banana plants with cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) (0.33) at 6 MAP. At 12 MAP, there were no significance differences in number of sucker developed by banana plants with cassava peel + Poultry manure + Siam weed + Mexican Sunflower ($C_PP_MS_WM_S$) (4.00) and cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) (3.87) but significantly ($p \leq 0.05$) different from the control (C) (1.70). Number of suckers developed by banana with cassava peel + poultry manure (C_PP_M) (3.00) was significantly ($p \leq 0.05$) different from number of suckers developed by banana plants with the control (C) (1.70).

Table 4.26. Effects of composts on number of functional leaves of large banana at fruiting phase

Treatments	Months after planting	
	12	**14**
C	10.33a	10.34a
C_PP_M	11.07a	10.48a
$C_PP_MS_WM_S$	11.00a	11.26a
$C_PS_WM_S$	11.07a	10.22a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.27. Effects of composts on plant height (cm) of large banana at fruiting phase

Treatments	Months after planting	
	12	**14**
C	112.62c	112.65c
C_PP_M	134.78c	135.28c
$C_PP_MS_WM_S$	159.61b	160.42b
$C_PS_WM_S$	175.49a	179.24a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.28. Effects of composts on leaf area (cm^2) of large banana at fruiting phase

Treatments	Months after planting	
	12	14
C	850.2c	844.3c
C_PP_M	2037.1b	2005.4b
$C_PP_MS_WM_S$	7103.7a	7158.4a
$C_PS_WM_S$	1431.1bc	1542.2b

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.29. Effects of composts on stem girth (cm) of large banana at fruiting phase

Treatments	**Months after planting**	
	12	**14**
C	9.66b	9.86b
C_PP_M	13.00ab	13.07ab
$C_PP_MS_WM_S$	14.29a	14.56a
$C_PS_WM_S$	13.22ab	13.32ab

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower

Table 4.30. Effects of composts on number of suckers developed from large Banana

Treatments	Months after planting		
	6	**9**	**12**
C	0.07b	0.67bdc	1.70c
C_PP_M	0.20b	1.00dc	3.00b
$C_PP_MS_WM_S$	3.00a	2.33bac	4.00a
$C_PS_WM_S$	1.00b	3.00ba	3.87a

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

Table 4.31. shows that the height of the tallest sucker at harvest was obtained in banana plants with cassava peel + Poultry manure + Siam weed+ Mexican sunflower ($C_PP_MS_WM_S$) (88.09 cm) and significantly ($p \leq 0.05$) different from the least in the control (C) (48.62 cm). The tallest banana plants at harvest were obtained in cassava peel + Siam weed +Mexican sunflower ($C_PS_WM_S$) (180.87 cm) which differed significantly ($p \leq 0.05$) from the control (C) (133.37 cm). There were no significant differences in plant height at harvest among the treatments cassava peel + poultry manure (C_PP_M) (171.57 cm) and cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) (160.53 cm).

4.14 Effects of formulated composts on yield of large banana

Weight of bunch at harvest in banana plants with cassava peel + poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) (10.87 kg), cassava peel + Siam weed +Mexican sunflower ($C_PS_WM_S$) (10.68 kg) and poultry manure + Siam weed + Mexican sunflower (C_PP_M) (10.83 kg) were not significantly different from each other. These values were higher, significantly ($p \leq 0.05$) different from banana with control (C) (8.96 kg). Number of hands per bunch of banana plants with cassava peel + poultry manure (C_PP_M) (10.93) and cassava peel + Siam weed + Mexican sunflower ($C_PS_WM_S$) (10.03) were not significantly different from each other but were higher and significantly ($p \leq 0.05$) different from banana plants with control (C) (6.43). Number of hands per bunch of banana plants with cassava peel + Poultry manure + Mexican sunflower + Siam weed ($C_PP_MS_WM_S$) (12.10) was significantly different from number of hand per bunch of banana with control (C) (6.43). The number of sucker at harvest of banana plants with cassava peel + poultry manure + Mexican sunflower + Siam weed ($C_PP_MS_WM_S$) (6.00) was the highest and significantly ($p \leq 0.05$) different from the control (C) (4.00) and cassava peel + poultry manure (C_PP_M) with the value of 4.00.

Table 4.31. Effects of composts on large banana at harvest

Treatments	Highest height of sucker at harvest (cm)	Plant height at harvest (cm)	Bunch weight of Banana at harvest (kg)	Number of hands per Banana bunch at harvest	Number of suckers at harvest
C	48.62c	133.37c	8.96c	6.43c	4.00c
C_PP_M	66.61b	171.57ba	10.83a	10.93b	4.00c
$C_PP_MS_WM_S$	88.09a	160.53ba	10.87a	12.10a	6.00a
$C_PS_WM_S$	82.35ba	180.87a	10.68a	10.03b	5.33ba

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability by DMRT.

C = Control (No compost),

C_PP_M = Cassava peel + Poultry manure,

$C_PP_MS_WM_S$ =Cassava peel + Poultry manure + Siam weed + Mexican sunflower,

$C_PS_WM_S$ = Cassava peel + Siam weed + Mexican sunflower,

CHAPTER FIVE

DISCUSSION

5.1 The Experimental Area of Study

The experimental field's soil had pH which was at end of the range 5.0-6.5 recommended for banana production (Pius and Marion 2004; Matt and Mellindar, 2016). This implies addition of certain nutrients becomes handy. Potassium content of the soil used was higher than the crucial threshold of 0.20 cmol/kg (FMARD, 2004). On the other hand, effective cation exchange capacity (ECEC) of the experimental field was less than 5 cmol/kg, this was in fact a sign of low soil fertility status and a hindrance for banana production. However, the soil condition could be improved upon for banana production with addition of mulch and composts for sustainable good yield. Time of planting banana cultivars on experimental field was December and had about 96 % plant survival throughout the experiments. Although, the experiment was rainfed but the initial stage of banana growth during dry season was carried out to ascertain and establish its unhindered survival with the addition of water for 14 weeks before onset of rainfall. This study showed that with good management and better agronomic practices, banana can be planted anytime of the year without any fear of crop failure. This study affirms the work by Gowens (1995) about the absence of seasonality in the production of banana. Similarly, water added at the initial stage of crop development was below the recommended amount (1500-2500 mm) simply because the rooting system at the take-off cannot be more than 500 mm in the first four (4) months on the field and taking field capacity of the experimental site to consideration. This also was in line with water supply suggested by Wilberforce (2001).

5.2 Performance of cultivars from Mulch application The performance of cultivars planted (large and medium) were looked into from mulch application. Large cultivar outperformed medium cultivar in stem girth, leaf area, plant height and other parameters measured at 6 MAP with exception of number of suckers developed. This could be traced to high soil temperature exhibited with the treatments on large banana cultivar which invariably stimulate biodegradation of mulch material and subsequent mineralization for plant use. Mulches with medium banana cultivar on the other hand conserved more moisture in the soil significantly more than large banana, this led to more suckers of medium banana cultivar developed at 6 and 9 MAP than large banana cultivar. Conservation of soil moisture, maintenance of soil temperature at both morning and afternoon time are likely to be reason for development of more suckers by medium banana cultivar than large bananas. Medium cultivar also developed more number of functional leaves than large banana cultivar at 9 MAP which was in accordance with Matt and Mellindar (2016). The morning soil temperature of medium cultivar at both 6 and 8 WAP were lower and significantly different from the large cultivar, this was likely to be the reason medium cultivar produced more functional leaves and developed more suckers than large cultivar. Plant height of large banana was higher at 6 and 9 MAP than medium banana cultivar; stem girth of large banana at 6, 9, 12 and 14 MAP was also higher than that of medium banana cultivar. This indicates that large banana cultivar responded greatly to mulch treatment and utilization than medium banana cultivar.

Leaf area of large banana cultivar was significantly ($p \leq 0.05$) different from the leaf area of medium banana cultivar at 6 MAP, this paved way for more leaf canopy cover and subsequent low soil temperature in the afternoon. Soil temperature of the experimental field indicated that soil temperatures taken in morning at 6 and 8 WAP of large banana were higher than those from medium banana cultivar. Medium banana recorded the highest soil moisture at both 6 and 8 WAP than large banana whereas there was no significant difference in soil moisture between the two cultivars at 10 WAP, partly because of onset of rainfall around that time. Large banana cultivar developed highest height of suckers at harvest, highest bunch weight at harvest and highest number of hands in bunch than medium cultivar. The average bunch weight at harvest of large banana was higher and significantly ($p \leq 0.05$) different from the bunch weight at harvest of medium banana. There was significant ($p \leq 0.05$) difference in mean number of hands/ bunch of large banana cultivar and the mean number of hands in bunch of medium banana cultivar.

Higher soil temperature at morning times could be responsible for the better large banana cultivar's performance and much lower soil temperature in afternoon around mulch plants which was likely to have increased microbial population, thereby fasten rate of biodegradation of mulch materials, mineralization and absorption of needed nutrients for banana plant growth, root development, preserving of soil structure (Toth *et al.,* 2007) and yield. Increase in soil temperature usually increase rate of chemical and biological reactions over flora and fauna on soils. Large banana out performed medium cultivar at vegetative, flowering, fruiting phases, this later transformed to higher yield parameters at harvest.

5.3 Mulch treatments influences on the growth and production of banana

Number of functional leaves are good indicator of a healthy plant as well as pointer to better performance of crops. Invariably, this parameter together with leaf area help banana to manufacture its food (Photosynthesis) adequately which be expressed in terms of the overall yield. McIntyre *et al*. (2003) found that the benefits of the mulch on the formation of biomass, banana foliage nutrition, and infiltration of water into the soil outweighed the drawbacks of increasing weevil populations. Fresh Mexican sunflower mulch (FMS) gave highest plant height at flowering phase of banana (9 and 11 MAP), FMS and DSW recorded highest stem girth (9 and 11 MAP) and highest leaf area (6, 9 and 11 MAP). The performance of the banana in leaf area up to 9 MAP was similar to the conclusions of Robinson *et al.* (1993). Fresh Mexican sunflower (FMS) gave the most significant difference in leaf area of banana among all the treatments at 9 MAP which was closely followed by dried Mexican sunflower (DMS). DMS+DSW developed more suckers significantly than other mulch treatments used at flowering phase (11 MAP).

Afternoon soil temperatures of all the plant mulch treatments were lower and significantly different from the control throughout the period from 6 to 12 WAP. This means the effect of mulch material is felt whenever it is applied as reflected in the afternoon soil temperature of the banana cultivars. All the mulch treatments were having same and non-significant different effect on afternoon soil temperatures. On the other hand, all the plant mulch treatments had higher (though not different from each other) soil moisture contents than the control that has deviance and lowest values throughout the periods of the study. At 14 WAP, there were no significant different in soil moisture content of banana plants with all the treatments used in the experiment. This could be attributable to the onset of rainfall in the experimental area. The probable reason adduced here could also be as a result of highest afternoon soil temperature recorded by control which could mean an increase in rate of soil moisture evaporation compared to other plant mulch treatments. This was an indication of effectiveness of the mulches in the applied areas of the experiment. This resembled the work of Pushparajah (1977). Mulch applied has greatly helped all the banana parameters measured exceedingly above control. Mexican sunflower and Siam weed type in their different combinations as mulch has helped in the production of Large Williams banana in Ibadan, Oyo state Nigeria.

Fresh Mexican sunflower (FMS) support more leaves development than other treatments used in the experiment; the reason here could be traced to the percentage of total nitrogen content of Mexican sunflower which was higher than total nitrogen of Siam weed. It means that fresh Mexican sunflower (FMS) if added as mulch will contribute to more leaf developments in banana production. Also, it was observed there were attraction of termites to fresh Mexican sunflower mulch and Dried Mexican sunflower on the field of study. These insects probably made degradation of Mexican sunflower faster; enhanced aeration of the soil, infilteration capacity and mineralization that facilitate quick response of the banana crop to the Mexican sunflower applied. This study proved it that fresh Mexican sunflower (FMS) attracts termites to the surface of the soil and thereby hasten biodegradation of the material as mulch unlike Siam weed mulch. Dried Mexican Sunflower and Dried Siam weed (DMS+DSW) mulch had the highest morning soil temperature at 8 WAP which was similar to Taiwo and Lawrence, (2014); then subsequently number of suckers developed at during fruiting phase at 14 MAP. This can be likened to potentials in DMS and DSW to jointly conserve temperature and preventing soil water surface evaporation. With the performance and response of parameters measured to mulch treatments over banana production, it can be inferred that the aspect of mulch in banana production should be taken serious from planting.

For parameters such as number of hand in bunch and bunch weight of Williams banana at harvest, fresh Mexican sunflower (FMS) significantly performed better than other plant mulch treatments applied in the study. This could be deduced from highest bunch weight of banana at harvest from banana plant with fresh Mexican sunflower (FMS) followed by banana plant with fresh Siam weed (FSW), while the least average bunch weight of banana was obtained from banana plants with control (C) treatment. This result concluded that mulching with different kinds of materials or of any kind tends to increase banana yield. Also highest number of hands per bunch was obtained from banana plant with FMS followed by banana plant with FSW. The values of the average weight and number of hands in bunch were numerically higher and significantly ($p \leq 0.05$) different from the values obtained from control. Highest number of sucker at harvest was recorded from banana plant with dried Mexican sunflower (DMS) while the highest height of sucker was recorded from banana plant with dried Mexican sunflower + dried Siam weed 1:1 (DMSDSW).

5.4 Yield obtained

The value of yield achieved in this experiment is less than recommended average banana yield partly because de-suckering exercise was not carried out throughout the expiration of the experiment. Numbers of suckers developed per banana plant was one of the parameters measured in the experiment. First and second ratoon crops (daughter and granddaughter) are expected to yield more than the main (mother) banana plants comparing the mineralization, usage of available nutrients, time of harvest of ratoon crops (4 months) and cost of expenses on ratoons in relations to 15 months of nurturing a new banana sucker from planting which will have been erased.

5.5 Composts Formulated Potentials

Of all the six cassava based composts formulated: C_P (Cassava peel), C_PP_M (Cassava peel + Poultry manure), $C_PP_MS_WM_S$ (Cassava peel + Poultry manure + Siam weed + Mexican sunflower),$C_PS_WM_S$ (Cassava peel + Siam weed + Mexican sunflower), C_PS_W (Cassava peel + Siam weed) and C_PM_S (Cassava peel + Mexican sunflower) only these three C_PP_M (Cassava peel + Poultry manure), $C_PP_MS_WM_S$ (Cassava peel + Poultry manure + Siam weed + Mexican sunflower) and $C_PS_WM_S$ (Cassava peel + Siam weed + Mexican sunflower) have great potentials and capacity to release nutrients to soil at different times as determined in the laboratory experiment of incubation study which lasted ten weeks.

The composts have different nutrient compositions and concentrations of macronutrients N, P, K, Ca and Mg. These macronutrients were determined differently at different stages but same intervals of incubation period. It was observed that the peak of nutrient release of these major elements varied from one compost to the other. Therefore, Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost ($C_PP_MS_WM_S$) has greatest potential in releasing available phosphorus to soil especially from 4 weeks after incubation (WAI). $C_PP_MS_WM_S$ increased phosphorus release to soil tremendously by incubation period. This shows that $C_PP_MS_WM_S$ compost has potential capacity to supply phosphorus to soils continually for crop production. If $C_PP_MS_WM_S$ is applied, it will continue to release its phosphorus to soil as crop is growing which is good for optimum crop production. Apart from phosphorus function in formation of foliage, it also functions in flowering and development of seeds in crop production. Reflection of this was seen in the effectiveness of the compost in assessing banana growth and yield. $C_PP_MS_WM_S$ compost had the highest concentration of total P as well as highest concentration of exchangeable Calcium among other composts. Invariably, the higher concentration of Calcium determined by the composts will help to improve soil structure and controls level of aluminium, manganese, magnesium and sodium ions in the soil (Aduayi and Ekong, 1981).

The compost $C_PP_MS_WM_S$ gave the highest and almost double amount of phosphorus compared to other composts to soil as from 4 WAI, 6 WAI, 8 WAI and 10 WAI. The C_P gave lowest amount of phosphorus to soil at both 8 and 10 WAI compared to the control. The reason could be the presence of Hydrocyanic acid (HCN) in C_P which might likely hinder release and availability of phosphorus another possibility is that the nutrient content of C_P was the lowest among all the nutrients determined in the laboratory. This compost: Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) performed best in the release of available phosphorus to soil than any other compost used in the experiment at all the stages of incubation except at 2 WAI. Other compost materials aside Cp gave good nutrient combinations though at different concentrations, this shows effectiveness of aerobic composting (Misra *et al.* 2003)

More of exchangeable calcium than exchangeable Potassium and exchangeable Magnesium were determined at every stage of the incubation in the experiment. $C_PS_WM_S$ compost prepared, had the highest total nitrogen content of and highest exchangeable potassium content. The value of total Nitrogen determined by the composts were in decreasing order from week 2 of incubation as period of incubation increases. A confirmation to the fact that Nitrogen is a volatile nutrient which is lost from the soil at a very fast rate. There were increases in total Nitrogen release by all the treatments on washed river sand at 10 WAI compared to the total Nitrogen release by all the treatments at 8 WAI. At 10 WAI all the composts determined more Nitrogen to the soil than the previous incubation periods. This compost Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) increased its Nitrogen release to soil by 97.01 % from 8 WAI to 10 WAI. It also has great potential in producing better yield if used as fertilizer. Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$) compost released the highest exchangeable potassium to soil during incubation period at 2, C_PM_S released the highest exchangeable potassium at 6 while $C_PS_WM_S$ released the highest exchangeable potassium to soil at 8 WAI. This means effect of $C_PP_MS_WM_S$, $C_PS_WM_S$ and C_PM_S composts were felt much by banana in its vegetative phase of 2 to 12 weeks after application.

Amount of potassium released to soil by all the composts except $C_PS_WM_S$ increases slightly as incubation period increases. This means the composts made have potentials of Potassium release to soil for banana production. This study enabled the researcher to know beforehand the release pattern of composts and the compost that held on to nutrients needed for banana vegetative and reproductive stages. There were variation and decrease in the concentrations of nutrient released by the composts on sand during incubation because the depth of extraction of sand samples was the same (15 mm) at each terminal period of experiment. Also there are continual mobility, vapourization of majority of the active nutrients from the sand medium.

The compost $C_PP_MS_WM_S$ (Cassava peel + Poultry manure + Siam weed + Mexican sunflower) had greatest influence on plant height, leaf area and stem girth which were higher than these same parameters from other compost treatments and significantly different from other composts at all the banana phases of the field experiment. This could probably be traced to the highest concentration of total P and exchangeable Ca in the compost and its readiness to mineralize for optimum crop utilization as observed also by Obatolu, (1995). Cassava peel + Poultry manure + Siam weed + Mexican sunflower ($C_PP_MS_WM_S$), $C_PS_WM_S$ (Cassava peel + Siam weed + Mexican sunflower) and C_PP_M (Cassava peel + Poultry manure) composts developed more suckers at fruiting phase of banana 12 MAP than in the control of the experiment. These composts $C_PP_MS_WM_S$, $C_PS_WM_S$ and C_PP_M also produced the highest bunch weight of banana in that order at harvest which invariably were different from the control in a substantial way. The broad performance of these composts could possibly be traced to the composition of nutrient concentration embedded in them (Williams, 2017) as well as release of important nutrients for banana growth and yield.

5.6 Effects of composts on Banana growth and Production

All the three composts: C_PP_M (Cassava peel + Poultry manure), $C_PP_MS_WM_S$ (Cassava peel + Poultry manure + Siam weed + Mexican sunflower), $C_PS_WM_S$ (Cassava peel + Siam weed + Mexican sunflower) used in experiment three (3) showed higher performance and significant difference from control numerically in the following parameters: highest height of sucker at harvest, average number of hands in banana bunch, bunch weight at harvest and banana plant height at harvest. This shows and proofs that adding organic fertilizer to soil will definitely increase crop yield as well as other benefits like soil structure improvement (Toth *et al.,* 2007), improvement of infilteration capacity, degradation of soil environment is put at check (Ipadeola and Adeoye 2014) prevention of water erosion, binding soil particles together, encouraging soil microbial activities among others. Organic mulch and composts were used in this study at Ibadan, South west Nigeria; while inorganic fertilizers of nitrogen and potassium were used to get higher yield values at Egypt. Some of the shots from the experimental plots are in figures 5.1, 5.2 and 5.3.

Williams banana produced highest bunch weight when both Ammonium sulphate at 20.50 % and potassium sulphate at 48.00 % were applied and minimum value was obtained from control (Mostafa, 2005). Number of hands per banana bunch in this

Figure 5.1. Mulching of the banana cultivars and measuring soil temperatures at vegetative stage

Figure 5.2. Banana Growth at Vegetative and Flowering phases

Figure 5.3. Williams Banana at Vegetative and fruiting phases

findings were identical to the findings of Mostafa (2005) despite the fact that inorganic fertilizers were not used at all in this research work. The average bunch weight values obtained of Williams banana at harvest in this experiments were below those obtained from previous studies and in commercial banana production partly because of fertilizer materials used were undiluted organic in nature, partly because of edaphic factors, native low soil fertility of the experimental field and partly because of de-suckering exercise that was not observed which also has direct impact on the fertility status, release of needed nutrients to the growing banana crops and absorption of needed nutrients. There will be more release of nutrients subsequently which will come with possibility of recording greater banana yield at harvest on first and second ratoon crops for second and third cycle of banana respectively. Moreover, cost of production will be effectively monitored and reduced over subsequent ratoons because banana plants will be going to fruiting at intervals of four (4) months. This will also boost profit margin compared to the first banana cycle. Esendugue *et. al*. (2007) reported that Williams was the best cultivar for commercial plantations in a tropical environment, and we would recommend using tissue-cultured plants for 6–7 years with proper management procedures to get the greatest results.

The entire work of this study was purely organic production which had no use of inorganic chemical substance from the beginning to the termination of the study. It was also ensured that neighbouring experiments did not use chemicals also to about 100 m apart from the experimental field of this study. Though supply of nutrients in a readily available form (inorganic) increases their availability in the soil quickly, however, none of them are taken up by plants or continue to exist in that form indefinitely (Lodhi *et al.*, 2009). The right utilization of inorganic inputs is undeniably important and has resulted in significant gains in crop yields in commercial agriculture both in Africa and throughout the world (Murwira, 2003). To this effect, organic crop production have been discussed with lots of advantages to mankind, hence the yield obtained should not be compared with when inorganic fertilizer was used. According to Pius and Marion (2004), for bananas to flourish, They require soils that are deep, bright, fertile, and have a pH of 5.0-6.5. The soil of this study area was just at the margin. Murwira (2003), stated organic inputs not only give nutrients to the soil, but they also aid in increasing the organic matter of the soil. But it's important to remember likewise observe that the foundation of organic matter management and cornerstone of any long- term gain in soil productivity. Depending on the kind of soil, different organic amendments, such as poultry manure, will have different effects on soil water infiltration (Adebayo *et al.*, 2019).

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This work investigated the use of two plant residues: Mexican sunflower and Siam weed in sole and combinations as mulching for growing two cultivars of banana (Williams-Large and Medium). The use of Mexican sunflower (fresh and dried) and Siam weed (fresh and dried) were used as mulching materials for Williams Large and Medium cultivars of banana. The work looked at the effect of the mulches depending on the soil's temperature and moisture content before the start of rainfall. The results showed that Large banana cultivar performed better than medium in plant height and stem girth throughout the periods of the experiment. However, medium banana cultivar developed more suckers than large banana. The reason adduced here was that medium banana cultivar conserved more soil moisture with the mulch applied than the large, a suitable condition for sucker development and microbial activities. Large banana gave higher values in plant height, stem girth and leaf area than the medium. Number of suckers and functional leaves of medium banana cultivar were higher and significantly different from large banana at 9 MAP. Mulch materials with Large banana induced higher soil morning temperature than mulch materials with medium banana cultivar, this was likely one of the reasons for faster degradation of mulching materials experienced in soils of large banana cultivar. Mulch materials with medium banana conserved soil moisture and had highest soil moisture content throughout the field work. Large banana had higher yield, weight of bunch at harvest and number of hands in bunch than medium banana cultivar. Treatment effects of mulching on banana indicated clearly that fresh Mexican sunflower performed best and closely followed by Fresh Mexican sunflower + fresh Siam weed 1:1 in all the parameters measured at nearly all the stages of growth. Stem girth and number of suckers developed from control (no mulch) had the least value compared to other mulch treatments. Treatments Fresh Mexican sunflower, Fresh siam weed, Dried Siam weed (DSW) and Dried Mexican Sunflower + dried Siam weed at ratio 1:1 had significant effects on banana cultivar in soil morning temperature. Highest number of hands in bunch and highest weight of banana bunch at harvest were obtained from banana plant with Fresh Mexican Sunflower mulch followed by banana plant with fresh Siam weed which were significantly different from the values obtained from control (C) treatment. Highest number of sucker at harvest was recorded from banana plant with dried Mexican sunflower (DMS) while the highest height of sucker was recorded from banana plant with dried Mexican sunflower + dried Siam weed at ratio 1:1.

The second stage of this study was experiment 2. It was an incubation experiment of some cassava peel based composts on washed river sand. The gradual release of five nutrients (N, P K, Ca and Mg) from the composts to washed river sand was studied progressively till the termination of the experiment at ten weeks. The rates of release of these nutrients were however progressively different from one stage of the experiment to another stage. Cassava peel + Poultry manure compost determined the highest total Phosphorus followed by Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost while the least total phosphorus was determined from control throughout the experiment. Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost has great potential and determined more total phosphorus to soil progressively towards the end of the experiment. Cassava peel when fortified with Poultry manure determined more and highest exchangeable potassium. It will take close to eight and ten weeks after application of Cassava peel + Siam weed + Mexican sunflower compost to get exchangeable potassium determined to soil and crop in abundance. All the composts had potentials and determined more total Nitrogen at earlier stage than subsequent periods of incubation. The least total Nitrogen determined by all the composts was obtained towards the termination of the experiment. More of calcium than Potassium and Magnesium were determined at every stage of the incubation in the experiment by all the composts made. Cassava peel + Poultry manure compost has more capacity to release greater amount of Magnesium at all stages of crop development as discovered in the incubation experiment.

The third stage was experiment 3. Effect of three composts (out of six prepared in experiment 2) were studied on growth and yield of large Banana cultivar that was chosen from experiment 1. Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost out-yielded other compost treatments in the following parameters: number of hands in bunch, bunch weight and height of sucker at harvest. Cassava peel + Poultry manure was rated the second best compost in Plant height, number of sucker developed, leaf area and stem girth. However, Cassava peel + Siam weed + Mexican sunflower compost did best over other compost treatments at every stage of the experiment. Banana plants with control (no treatment) had the least response on most of the parameters measured. This means banana will respond and yield optimally if either Cassava peel + Siam weed + Mexican sunflower compost or Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost is applied as organic fertilizer.

Conclusively, Banana production will be sustainable if mulching with fresh Mexican sunflower is made a routine cultural practice. This is evident in the yield of all banana mulch in this experiment that was significantly higher than the yield obtained from other mulch combinations and control. This study also made it clear that banana crop can be grown anytime of the year if both edaphic and climatic factors are put in serious consideration from the onset of cultivation. With the type of soil of (NIHORT) experimental area which is Alfisol, farmers in Nigeria particularly Oyo state, growing Williams banana can solely rely on the use of Cassava peel + Poultry manure + Mexican sunflower + Siam weed compost or Cassava peel + Siam weed + Mexican sunflower compost for better performance and sustainability of the crop. Yield obtained in this study was lower than those from other studies because de-suckering exercise was not done at all, throughout the study as number of suckers and highest height of suckers were part of parameters measured. Another factor that could probably cause low yield was the sole use of organic fertilizer. Yields from ratoon crops are expected to be more as mineralization of appropriate nutrients will promote further crop performance. Other compost that contain cassava peel performed lower on the parameters measured both at the growing stages and at fruiting, this low performance of banana response could be traced to certain amount of Hydrogenic glucocide of Hydrocyanic acid (HCN) in cassava peels which were likely to hinder or prevent availability of required nutrients needed for optimum performance of the banana crop. It must be emphasized that the utilization of organic materials as fertilizer gradually release nutrients for crop utilization unlike when inorganic fertilizer is used.

6.2 Conclusion

Based on the findings of this investigation, the followings were concluded

1. This study has been able to successfully screened two banana cultivars (Large and Medium) coming out with Large cultivar when it outperformed medium cultivar in most of parameters measured including the yield.
2. This study concluded application of Fresh Mexican Sunflower at rate of 15.1 ton/ ha can make banana production sustainable
3. Six cassava peel compost mix were screened to three: Cassava peel + Poultry manure, Cassava peel + Poultry manure + Siam weed + Mexican sunflower and Cassava peel + Siam weed + Mexican sunflower based on their different potentials and ability to release needed nutrients appropriately.
4 Composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%) or cassava peel, Siam weed and Mexican sunflower (70% +15%+15%) can be used to grow banana

6.3 Recommendations

1. It is recommended that for mulching of banana, sole use of fresh Mexican sunflower or fresh Siam weed enhanced more than overall banana yield than combination of fresh or sole dried form of the two materials. Mexican sunflower as a mulch material has greater influence in termite invitation to banana plantation in the experimental site which has helped in breakdown of plant materials and its utilization. Mexican sunflower (fresh and dried) mulch actually gave better performance over Siam weed as mulch in for banana growth and yield.
2. For effective and well grown banana in Nigeria, adequate water application at least 3 times a week as recommended should be practiced if

planting of the banana is made in the dry season as done in the first experiment of this study.

3. Composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%) or cassava peel, Siam weed and Mexican sunflower (70% +15%+15%) is recommended for optimum banana yield
4. Banana number of hands per bunch was highest in composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%) and recommended for commercial purpose

This study is open to further findings with treatments applied in first and second ratoon or daughter crop for Williams banana cv. An improved yield in bunch weight above first cycle is most likely to be obtained under good weed management.

6.4 Contributions to Knowledge

1. Sustainable Banana production using mulching with fresh Mexican sunflower as a worthwhile routine cultural practice
2. Fertilizer use efficiency of cassava peel can be improved by fortifying with poultry manure, Siam weed and Mexican sunflower
3. Three major cassava peel based compost mix were established based on their ability to release potassium nutrient
4. Composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70% +10%+10%+10%) or cassava peel, Siam weed and Mexican sunflower (70%+15%+15%) had highest potassium nutrient release
5. Composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%) or cassava peel, Siam weed and Mexican sunflower (70% +15%+15%) is recommended for optimum banana yield
6. Banana number of hands per bunch was highest in composted cassava peel, poultry manure, Siam weed and Mexican sunflower (70%+10%+10%+10%).

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APPENDICES

APPENDIX 1

Quantity of potassium recommended for optimum banana production is 600 kg ha^{-1}

Population density of banana at 2 m x 3 m in 1 ha of land is 10,000 m^2/6 m^2 = 1667

Quantity of potassium required by one banana plant 600/1667 = **0.36** kg

Available potassium in the study area = 0.3 cmol/kg (Table 4.1)i. e. 0.3 x 390 = 117 mg /kg

117 x 2.24 = 262.08 kg/ha/k

Quantity of k available in the soil to each banana plant is 262.08/1667 = **0.157 kg**

For this experiment,

Quantity of K needed to apply per banana plant =quantity of K recommended for optimum banana production minus quantity of K available in study area i.e.**(0.36-0.157) kg = 0.203 kg** / banana plant

Quantity of K needed to apply to each banana plant either through mulch or through compost in the study area is 0.203 kg.

APPENDIX 2

Quantity of Siam weed needed to apply per banana plant

Potassium (K) in Siam weed is 51.2 g /kg (Table 4.2)

It means 51.2 kg K will be supplied by 1000 kg dried Siam weed

so, 0.203 kg K needed will be supplied by 1000/ 51.2 x 0.203 = 3.96 kg dry weight Siam weed

A 3.96 kg dry weight of Siam weed is needed to apply to each banana plant in the study area.

This translates to 3.96 x 5.4 of fresh weight of Siam weed going by the ratio of dry matter content to fresh weight of Siam weed. Ratio of fresh weight to dry weight of Siam weed after oven dry at a constant weight of 70 ^{o}C was 5.4:1 i.e. 5.4 kg fresh weight of Siam weed supplies the same quantity of Potassium as 1 kg dry weight of Siam weed. This means 3.96 kg dry weight of Siam weed has the same dry matter content as 21.38 kg of fresh weight of Siam weed.

Fresh Siam Weed (FSW) = 21.38 kg

Dried Siam Weed (DSW) = 3.96 kg

½ FSW= 10.69 kg

½ DSW = 1.98 kg

APPENDIX 3

Quantity of Mexican sunflower needed to apply per banana plant

Potassium (K) in Mexican sunflower is 51.1g/ kg (Table 4.2)

It means 51.1 kg K will be supplied by 1000 kg Mexican sunflower

So, 0.203 kg K needed by each banana plant will be supplied by 1000/51.1 x 0.203 = 3.97kg dry weight Mexican sunflower

A 3.97 kg dry weight of Mexican sunflower is needed to apply to each banana plant in the study area.

This translates to 3.97 x 10.4 of fresh weight of Mexican sunflower going by the ratio of dry matter content to fresh weight of Mexican sunflower. Ratio of fresh weight to dry weight of Mexican sunflower after oven dry at a constant weight of 70^o was 10.4:1 i.e. 10.4 kg fresh weight of Mexican sunflower supplies the same quantity of potassium as 1 kg dry weight of Mexican sunflower. This means 3.97 kg dry weight of Mexican sunflower has the same dry matter content as 41.30 kg of fresh weight of Mexican sunflower.

Fresh Mexican sunflower (FMS) = 41.30 kg

Dried Mexican sunflower (DMS) = 3.97 kg

½ FMS = 20.65kg

½ DMS = 1.99 kg

APPENDIX 4

Quantity of Water applied per banana

Plough layer is 0-15 cm = 0.15 m

Recommendation of a range of 2000 – 2500 mm water was recommended for growing banana based on the soil characteristics, field capacity and rate of evapo-transpiration.

At planting of banana plantlets in December to the start of rainfall by March the following year, the rooting of banana planted was put at less than 30 cm i.e 0.3 m

For 0.3 m depth, water required is calculated

Area of 1 ha = 10,000 m^2

Vol of water in 1 ha at 0.3 m depth = Area of land x Soil depth

10,000 m^2 x 0.3 = 3,000 m^3

1 m^3 = 1000 litres

So, 3, 000 m^3 = 3, 000 x 1,000 = **3 x 10^6 litres of water / ha / annum**

1ha has 1667 banana plants

Implies, 1 banana plant will need $\frac{3 \times 10^6}{1667}$ = **1799 litres / annum**

In a month, amount of water needed per banana plant = $\frac{1799}{12}$ =149.9 = 150 litres

In a week, amount of water needed per banana plant = $\frac{150}{4}$ = 37.5 litres

At each watering (3 times / week), volume of water needed = $\frac{37.5}{3}$= 12.5litres

APPENDIX 5

The Quantities of Compost Treatments Applied Per Banana Plant

4A Quantity of Cassava peel + Poultry manure C_PP_M needed to apply per banana plant

From table 4.11, amount of k in Cassava peel + Poultry manure is 8.95 g kg^{-1}

That is 8.95 kg k will be supplied by 1000 kg of Cassava peel + Poultry manure compost C_PP_M

Therefore, 0.203 kg k needed by each banana plant (Appendix 1) will be supplied by 1000/8.95 x 0.203 = 22.68kg C_PP_M

C_PP_M = 22.68 kg per banana plant

4B Quantity of Cassava peel + Poultry manure + Siam weed + Mexican sunflower $C_PP_MS_WM_S$ needed to apply per banana plant

From table 4.11, amount of k in Cassava peel + Poultry manure + Siam weed + Mexican sunflower is 11.93 g kg^{-1}

That is 11.93 kg k will be supplied by 1000 kg of Cassava peel + Poultry manure + Siam weed + Mexican sunflower compost $C_PP_MS_WM_S$

Therefore, 0.203 kg k needed by each banana plant (Appendix 1) will be supplied by 1000/11.93 x 0.203 = 17kg $C_PP_MS_WM_S$

$C_PP_MS_WM_S$ = 17kg

4C Quantity of Cassava peel + Siam weed + Mexican sunflower $C_PS_WM_S$ needed to apply per banana plant

From table 4.11, amount of k in Cassava peel + Siam weed + Mexican sunflower is 26.13 g /kg

That is 26.13 kg k will be supplied by 1000 kg of Cassava peel + Siam weed + Mexican sunflower compost

Therefore, 0.203 kg k needed by each banana plant (Appendix 1) will be supplied by 1000/26.13 x 0.203 = 7.77 kg

$C_PS_WM_S$ = 7.77 kg

APPENDIX 6

Experiment 2- Incubation study

15 tonne compost or organic fertilizer recommended for 1 ha of land

Implies 15 x 1000 kg compost recommended for 1 ha of land

Weight of 1 ha of land is 2,240,000 kg ie 2.24×10^6kg (at 0-15 cm soil depth)

Meaning 2,240,000 kg soil will receive 15,000 kg compost

2,240,000 x(1000)g soil will receive 15,000 x (1000)g compost

2.24×10^9g soil will receive 15×10^6g compost

50g soil will now receive $\frac{15 \times 10^6}{2.24 \times 10^9} \times 50$

$$= \frac{15 \times 5}{2.24 \times 10^2}$$

$$= \frac{75}{224} = 0.335$$

= **0.34**g compost