KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

DEPARTMENT OF CROP AND SOIL SCIENCES

THE RESPONSE OF FIVE CASSAVA (*Manihot esculenta*) VARIETIES TO DIFFERENT MULCH MATERIALS

by

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I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

A study was carried out at the plantation section of Faculty of Agriculture KNUST to evaluate the effect of five mulching materials on the soil physical properties (soil water content, soil temperature and soil bulk density), growth and yield of cassava varieties. The mulch treatments evaluated were cocoa pod husk, guinea grass, pueraria, rice husk and rice straw plus a control treatment. The varieties used were Afisiafi, Ampong, Debor, Dokuduade and Essan. The land was ploughed and harrowed and the plots were marked out. Stem cuttings were obtained from Crops Research Institute, Fumesua. Cuttings were planted at 1m x 1m spacing.

The experiment was a 5x6 factorial arranged in a randomized complete block design. Each treatment was replicated 3 times. Planting was done on 28th October, 2010.

Following planting, soil samples were collected at random spots for laboratory analysis. Samples were also taken from the various mulch materials for laboratory analysis. Mulching was done a month after sprouting at the rate of 2 kg plant^{-1} in ring of about 20cm from the plants and a thickness of about 2cm. Soil and plant data were taken during the experiment.

The results showed that soil temperature and bulk density were significantly reduced by mulching. Soils moisture content was also markedly improved by mulching. Growth and yield and components of yield data were all markedly enhanced following the mulch application. However, the starch content of tubers was not affected by mulching.

The results again indicated that mulching improved soil physical properties which resulted in better growth and increased tuber weight and tuber yield. Among the mulch materials, rice husk produced the greatest effect in tuber weight, top plant weight, tuber yield and harvest index. The results showed that cassava cultivation can be enhanced through mulch application.

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DEDICATION

I dedicated this work to my loving mother Mrs. Logosu and to my senior brother Anthony Kwabena Logosu

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CHAPTER ONE

1.0 INTRODUCTION

Tropical tuber crops are an important source of carbohydrates in the developing nations, especially among the resource poor and rural populations. They are planted by millions of people in the tropics, and are also identified to be the major source of carbohydrates for the populations of the world in the next decades (Scott *et al.*, 2000). Their importance lies from the ability to produce harvestable materials in marginal soils and under adverse edaphic and climatic conditions (Iglesias *et al.*, 1996).

Most tropical tuber crops are not managed optimally, thus, resulting in low yields. Amongst the most important factors affecting yield of tropical tubers, soil moisture is considered a vital factor as it affects root development and hence could impose a significant impact on yields (Yamauchi *et al.*, 1996). However, in most regions where tropical tubers are cultivated, crops are exposed to moisture stress due to erratic rainfall and the unavailability of irrigation (Turner, 2000).

Cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) are two of the most popular tropical tuber crops (Scott *et al.*, 2000). Their wide use in both the tropical and some regions of the temperate countries make them the most widely grown species of tropical tubers, in comparison to species such as yam. However, their growth, development and yields are reduced significantly by soil moisture stress, and this is attributed to changes in root systems of these species due to variations in the available moisture for development (Agili and Pardales, 1999).

Cassava is grown for its root tubers as a subsistence and staple crop and often as a famine reserve crop. The fresh tubers contain 35% carbohydrate and less than 2% crude protein. The leaves can be used as pot herbs. Cassava ranks as the most important root crop in terms of world production before sweet potato. The cultivated species of cassava is not known in the wild state but it is thought that there were two major sites of speciation, in northern Brazil and in Mexico. Spread of the crop from these regions can be mainly attributed to Europeans in their trading and colonization activities. Cassava is a crop that gives high returns from limited labour and other inputs. Although under optimum conditions yields up to 50 t/ha can be obtained, average yields are around 8 t/ha (Gibbon and Pain, 1988).

Cassava plays a major role in alleviating the food crisis under marginal conditions in Sub-Saharan Africa (Hahn *et al.*, 1987). The areas where cassava was introduced earlier are now the most densely populated parts of Africa. These are eastern Nigeria, eastern and northern Tanzania, western Democratic Republic of Congo and Coastal West Africa (Akorada, 1994).

Since the Second World War, cassava has largely replaced yam in many areas in West Africa as the most popular root crop in terms of production, mainly because it is easier to grow even on poor soils and yields are generally higher than either yams or cocoyam (Onwueme, 1978). World production of cassava in recent years is more than 160 million tons annually, of which production in Africa south of the Sahara in the Cassava Delt has increased from about 50 million tons in 1980 to more than 90 million tons in 1993 due to high productivity of new varieties now available to Africa farmers. Nearly 30 million tons of the crop is produced in South America and over 50 million tons in Asia, mainly in Thailand and Indonesia. The largest producers in Africa are Democratic Republic of Congo (11%) and Nigeria (9%) of the world output (Martin, 1970; Otoo, 1996).

Cassava is the most important root crop in Sub-Saharan Africa, and practically all of Africa's over 50% production of the world's output of the crop is used for domestic consumption. In fact, in four countries in Africa- Democratic Republic of Congo, Central Africa Republic, Malagasy Republic and Congo Republic, more than 60% of the caloric intake comes from root crops and cassava represents 70% of this intake. In most countries in West Africa, notably Nigeria, Benin, Togo, Cameroon, Ghana and Code d'Ivoire, cassava plays a very significant role in the national diet (Anon, 1990).

In Ghana, cassava was widely cultivated around Accra in 1785 and was well-established by the beginning of the 19th century as food crop in the coastal areas of erratic and unreliable rainfall, farmers in the forest zone did not easily take to its cultivation, until a series of famines in the late 1930's and early 1940's proved its worth as a famine relief crop. Most intensive areas of production in Ghana are situated in the Accra-Winneba Plains, the Ho-Keta plains and the southern edges of the forest zone (Suhum-Nsawam-Adawso) (Cofie, 1950; Doku, 1989).

The limitations on the productivity of cassava are mostly related to poor traditional cultivation practices which may be summarized as follows:

- The system of cultivation in which cassava generally comes at the end of a rotation.
- The use of low-yielding traditional cultivars. There is a strong preference for traditional varieties which do not perform well and are more susceptible to diseases and pests.
- The use of unimproved agronomic practices and lack of capital to purchase inputs such as fertilizers.
- Attack by a multitude of diseases and pests.
- The absence of a steady, sufficiently profitable market because of the bulky nature of cassava, its short shelf life and the fact that traditional consumer preferences and dishes in many areas favour the unprocessed or raw products.
- The rapid decrease of the fertility of the soil, due mainly to poor soil and crop management (Tweneboah, 2000).

The management of upland soils for continuous and sustained crop production with economic input levels still poses a major difficulty in most parts of the tropics. Thus, appropriate soil management practices for specific crops and agroecological zones aimed at sustaining high crop yields and preventing soil degradation are one of the key factors in the development of sustainable tropical agricultural systems (Lal and Kang, 1982). Mulching is one of the management practices for increasing water use efficiency and weed control in crop fields (Unger and Jones, 1981). The considerable potential for improving soil organic matter levels and crop yields through the application of organic materials is widely recognized (Titiloye, 1982; Rayer and Chirroma, 1990).

The relative neglect of residue mulch materials may be partly because of their high C/N ratio, lignin /N ratio and hence the comparatively longer time needed for decomposition and nutrient release. In East Africa, where such materials are widely used in plantation crop gardens, they have been found to be a valuable source of plant nutrients (Mehlich, 1965; Michori, 1981). Quantitative assessments conducted in Nigeria by several researchers, including Okigbo (1972), Obatolu (1987) and Iwuafor *et al.*, (1990) have also highlighted the beneficial effect of residue mulch materials on the performance of selected annual crops and coffee seedlings.

Unprotected bare soil surfaces are prone to severe accelerated soil erosion Lal (1976) and overall soil degradation (Nye and Greenland, 1964). The high susceptibility of tropical soils to erosion and other degradative factors have made it necessary to integrate appropriate mulching techniques into tropical agricultural system in order to sustain the productivity of these soils (Mulongoy and Merckx, 1993).

Protecting the soil surface with mulch helps to improve the soil environment for optimal crop growth and yield. Surface mulch tends to minimize wind and water erosion, increase soil moisture and nutrient level, promote favourable soil structure through enhanced biological activity, moderate soil temperature and suppress weed growth (Lal, 1975a, 1975b; Fernandes and Sanchez, 1990; Salau *et al.*, 1992).

Again, mulching controls the water infiltration rate into the soil, by breaking raindrops impact energy. This ensures that the water seeps gradually into the soil and reduces surface flow. When a soil is mulched, crusting, which clogs soil pores and reduces the infiltration of water is diminished. Mulching reduces the caking of soils caused by the high absorption of heat or solar radiation (Orkwor *et al.*, 1998).

In addition, moisture distribution in the upper soil layer is more uniform in mulched soil compared to unmulched soil which results in more roots been developed in the upper soil layer which is usually richer in nutrient and useful micro-organisms (Lippert *et al.*, 1964; Knavel and Mohr, 1967). In irrigated saline soils, soil mulch reduces salt concentration inside the mulched areas because of lower evaporation under the mulch (Atherton and Rudich, 1986). In Latin America and Papua New Guinea, studies have shown the benefits of applying mulches to cassava and sweet potato to stabilize yields (Ossom *et al.*, 2001).

The objectives of this work were to determine:

- The effect of mulching on soil temperature and soil moisture content.
- The impact of mulching on the growth and yield of cassava.
- The best mulching material that will influence growth and yield of cassava.

CHAPTER TWO

2. 0 LITERATURE REVIEW

Soil fertility maintenance has become a serious problem with the removal of vegetation and continuous cropping. The indicators are rapid decline of organic matter and soil nutrients, high soil acidity and erosion resulting in sharp decline in crop yields. The numerous soil problems are further compounded by the seasonality and erratic distribution of rainfall which results in varying periods of dry spells separated by wet periods (Enwezor *et al.*, 1981). Such dry spells create problems in crop production in that crops are subjected to severe moisture stress which could lead to total crop failure if it coincides with critical growth periods. On the other hand, during periods of heavy rainfall, when field crops have not yet developed sufficient canopy to dissipate raindrop impact, erosion becomes a very serious problem. Furthermore, high temperatures experienced in the area, encourage excessive evapo-transpiration which ultimately leads to severe soil moisture stress (Uwah and Iwo, 2011).

Mulch provides a better soil environment, moderates soil temperature, increases soil porosity and water infiltration rate during intensive rain and controls runoff and erosion as well as suppresses weed growth (Bhatt and Kheral, 2006; Anikwe *et al.,* 2007; Sarkar and Singh, 2007; Glab and Kulig, 2008). Organic mulches perform additional functions of increasing soil organic matter content, cation exchange capacity (CEC), enhance biological activity, improve soil structure and increase plant nutrients after decomposition (Tian *et al.,* 1994; Lal, 1995). Mulching improves plant growth, yield and yield quality (Sharma and Sharma, 2003; Singh *et al.*, 2007). Gill *et al.*, (1996) stated that yield increase with mulching was also greater for the early season crop. Some authors point out that increase in grain yield by mulching is attributed primarily to decrease in soil temperature and improved soil moisture regime (Lal, 1974).

2. 1 DEFFINITION OF MULCH AND MULCHING

Any material used at the surface of a soil primarily to prevent the loss of water by evaporation or to keep down weeds, may be designated as mulch (Lyon *et al.*, 1952). The coverage of agricultural soils with materials is known as mulching. Muller-Samnn and Kotschi (1994) have defined mulching as "a crop husbandry in which organic or inorganic material is spread over the soil surface to influence the physical, chemical and biological properties of the soil and its microclimate with the aim of improving the productivity of a site".

2. 2. TYPES OF MULCHES, THEIR SOURCES AND APPLICATIONS

Many kinds of natural and artificial mulching materials have been used in agriculture such as weeds, crop residues, branches, animal manure, stone chippings Brandjes *et al.*, (1989); IITA (1994), aluminum foil, petroleum by-products plastic films Masoum *et al.*, (1998), wheat straw, rice straw or husk, grass, wood, sand, oil layer (Khurshid *et al.*, 2006; Seyfi and Rashidi, 2007). The mulching material should be free from pests, diseases, weed seeds, toxins and other problem-causing materials (Okugie and Ossom, 1988). Beside its application to the whole field surface, the mulching material can be applied between crop rows (in bands) or around single plants in case of tree crops (Adam *et al.*, 2009).

2. 2. 1 Crop and Food Waste

A number of wastes from crop and food processing have been used as mulches. These include cocoa shells, coffee grounds, ground corncobs, ground tobacco stems and sugarcane. Cocoa shells are brown, light, easy to handle, and relatively non combustible. Cocoa shells have some values as a fertilizer and resist blowing in the wind. Their high potash content harms some plants, so they should not be applied to depth greater than 5.0 cm. Ground coffee cakes badly hence a depth of 2.54 cm is recommended. It contains some nitrogen. Ground corncobs make good mulch. Some find their light colour objectionable. Ground tobacco stems make coarse, good mulch with some nitrogen value. They should not be used on plants susceptible to tobacco mosaic virus, since they can be a source of infection. Sugarcane is good mulch when available in the crushed form. It has a moderately acidic pH, making it useful around acid-loving plants (Poincelot, 2004).

2.2.2 Garden and Yard Wastes

Compost makes good mulch, because it has value as a fertilizer and a soil-like appearance. It is also a good organic amendment for tilling into the soil after the growing season ends. Grass clippings contain nitrogen but cannot be applied thickly when green, because they heat rapidly and form dense, matted layer that restricts the flow of air and water. They should be applied in thin layers and allowed to brown between each application. Leaves are free, readily available in many areas, release some nutrients on decomposition and spread easily. However, they have a tendency to form a soggy, impenetrable mat. This problem can be overcome by mixing leaves with fluffy materials such as hay or straw or leaves shredding (Poincelot, 2004).

2. 2. 3 Manufactured Materials

Polyethylene film is one of the few mulches that is readily available, adaptable to machine installation, and economical enough to be used in large-scale commercial applications. Polyethylene allows passage of gases such as nitrogen, oxygen, and carbon dioxide. Holes or slits facilitate the planting of seeds or plants and water entry. Some types come with perforations. It can last several years if undamaged by machinery and is usually black. Clear film is sometimes used, but it offers limited weed control (unless herbicide is applied before mulching), sun light passes through it. Earlier crops can be produced with the clear, and to a lesser degree, black plastic mulches because of the warming of the soil (Poincelot, 2004).

2. 2. 4 Natural Products

Straws, hay, and salt-marsh hay are lightweight and easy to apply, but their appearance restricts their application mostly to vegetable gardens. These materials are available in spoiled form from animal feed dealers at cheaper prices. They are used more frequently as winter mulch for protection. They are not long lasting and frequently contain weed seeds. Stone in crushed or gravel form is durable as mulch with an attractive appearance. It is used often around trees or shrubs (Poincelot, 2004).

2. 2. 5 Wood By-Products

Wood by-products include bark, sawdust and wood chips. Aged or partially rotted sawdust makes satisfactory attractive mulch that lasts a long time. Because it is prone to caking and has a high C/N ratio, it is applied only 5.0 cm deep after adding nitrogen fertilizer to the soil. Bark is widely sold, popular horticultural mulch. Small pieces of bark are preferred over large chunks. Bark mulches vary, but all are attractive, durable, and suitable for foundation shrub plantings. Contact with wood framing is to be avoided, because it can be a termite vector. The high C/N ratio of bark requires prior application of nitrogen fertilizer. Wood chips are moderately priced or free, attractive, readily available, and easy to apply. They make excellent mulch. Their high C/N ratio requires an application of nitrogen fertilizer prior to placement of the mulch. It can last for about 2 years. As with bark mulch, one must consider termites (Poincelot, 2004).

2. 2. 6 Stubble mulch

Stubble mulch is somewhat different from those already described, especially as to the mode of establishment. In this case, the mulching materials have been grown in place and consist of the refuse of the previous crop. Oats, straw, corn stalks and like residues are good examples. By the use of suitable implements a seedbed can be prepared and the crops planted, leaving the organic trash on the surface to act as mulch. In the case of row crops, modified tillage implements make cultivation possible without greatly disturbing the surface layer. Although the use of stubble as mulch has been found to conserve moisture in some cases, however, its main effectiveness seems to be that of controlling wind erosion (Duley and Russel, 1942).

2. 2. 7 Soil Mulch

All mulches discussed above are more or less foreign to the soil, merely covering its surface, thereby obstructing evaporation and at the time preventing weed growth. With proper tillage and favourable weather, a loose, dry layer of soil 3-5cm deep may be established on the surface by sacrificing much of water it contains. This layer, the soil mulch, tends to obstruct the upward capillary adjustment of water from the moist soil below and should reduce evaporation losses to a considerable degree. This interruption in the upward capillary transfer of water by the soil mulch seems to be due to:

- Its lack of close contact with the moist horizons underneath.
- An increase in its non capillary pores and a reduction in those favouring capillary.
- The resistance to wetting that most dry soils exhibit (Call and Sewell, 1917).

2. 3. EFFECTS OF MULCHES ON SOIL PROPERTIES

2. 3. 1 Soil Temperature

Soil temperatures are influenced by soil cover and especially by organic residues or other type of mulch placed on the soil surfaces. Mulches are soil temperature modifiers. In periods of hot weather, they keep the surface of the soil cooler than where no cover is used. In contrast, during cool spells in the winter, they moderate rapid temperature declines and tend to buffer extremes in soil temperatures. The afternoon (12–16 hr) temperatures measured at 5cm depth under the straw mulch were considerably lower (31 - 33 ^{O}C) than those of the bare soil temperatures (32 – 37^{O}C) above 35 ^{O}C which often depress root function and plant growth (Brady and Well, 1996).

Zhang *et al*., (2009) compared three mulching treatments, control, rice-straw mulch and gravel mulch. Based on the study of Sharma *et al*., (1985), the thickness of mulch was kept at 3 cm. The average soil temperature at every depth from 7cm to 97cm was higher under gravel and straw mulches than under control but the difference did not generally reach the level of significance. Only at 17 and 47 cm depths the average temperatures during winter were significantly higher under gravel much (10.25 ^{O}C and 9.67^{O}C) and straw mulch (9.87 and 9.45 ^{O}C) than under control (8.05 and 8.97^{O}C) respectively. During spring again, significantly higher average temperatures were recorded for 17 cm depth under mulching treatments; straw much (23.14^{O}C) and gravel mulch (23.11^{O}C) than under control (19.53^{O}C). Li (2003), Rahman *et al*., (2005) reported increase in soil temperature due to mulching in winter cropping season.

Three treatments, ridge (mulched and unmulched), mound (mulched and unmulched) and zero (mulched and unmulched) were evaluated. The impact of mulch on afternoon soil temperatures at 0-10 cm depth reveals that unmulched plots exhibited a higher temperature (31.8-39.6°C) than mulched plots (27.2 -34.9°C), while mulch had a mean soil temperature of 29.5°C, that of unmulched was 33.9°C. Mulch suppressed the mean soil temperature by 4.4°C. A difference of 2-7°C between mulched and unmulched plots during the early planting season was observed in Western Nigeria (Olasantan, 1999). The difference in soil temperature among the mulch types is statistically significant. While soil temperature is supra-optimum in the months of February (36.5°C), March (39.40°C), April (35.8°C) and November (35.6°C) at 10 cm depth in unmulched plots, such condition was only experienced at the peak of the heat wave in March (35.6°C) for mulched plots. Even at 20 cm depths supra-optimum temperature conditions were noticed in unmulched treatments in the months of March (36.1°C) and April (35.4°C) Odjugo, (2008). This is in agreement with earlier findings, which observed supra-optimal soil temperature in unmulched treatment in the middle belt of Nigeria (Song, 2003).

Treatments such as straw (chopped wheat straw), peat (medium decomposed fen peat), sawdust (from different tree species), grass (regularly cut, from grass-plots) applied at 5-cm and 10-cm thick layer shortly after sowing and without mulching were evaluated. All examined organic mulches significantly decreased soil temperature. The temperature differences of 0.7-1.6°C were observed between plots without mulch and those mulched with straw (Sinkevičienė *et al.*, 2009). Reduction of soil temperature is of great importance in countries with hot climate conditions, but now, as the climate is warming, conditions for temperate crops are becoming unfavourable. For example, potato growth and yield are highly affected by high temperature, especially mean temperature above 17°C (Caldiz *et al.*, 2001).

Three mulch treatments applied at rate of 10 t ha^{-1} (straw mulch), 800–850 mm width with 0.009 mm thickness (polythene mulch) and 1 kg ai ha^{-1} mixed in 1000 l ha^{-1} of water (chemical mulch) compared with an unmulched control showed that different mulching materials have varying effects on soil temperature (Ramakrishna *et al.*, 2006). These are consistent with the results of Hanada (1991) who observed that polythene films (black, green or transparent) markedly increase soil temperature compared to grass mulch in temperate, sub-tropical and tropical regions. Dionne *et al.*, (1999) observed that insulating material covers such as wood mat and straw affect the soil temperature, and the characteristics of protective soil covers also influence the soil temperature variation range

2. 3. 2 Soil Moisture Content

Three treatments ridge (mulched and unmulched), mound (mulched and unmulched) and zero (mulched and unmulched) were evaluated. At all depths, soil moisture content were higher in the mulched than in the unmulched treatments. At 0-15 cm depth, mulched treatment had a soil moisture mean of 38 g/g which was significantly higher than unmulched (25 g/g). Mulch therefore, improves the soil moisture regime by decreasing losses caused by surface run-off and evaporation and increases the infiltration capacity during rainfall (Odjugo, 2008). This agrees with earlier works in Nigeria by (Halugalle *et al.*, 1990; Olasantan, 1999).

Three mulch levels of wheat straw applied at the rate of 0, 7 and 14 Mg ha^{-1} significantly affected the soil moisture contents, the maximum soil moisture contents were observed in 14 Mg ha^{-1} (17.0%), followed by 7 Mg ha^{-1} (15.8%) and minimum in 0 Mg ha^{-1} (14.0%). The interactive effect of tillage and mulch was significant, the higher moisture contents were observed in conventional tillage with 0Mg ha^{-1} (17.8%) and minimum in deep tillage with 14 Mg ha^{-1} (13.4%) (Pervaiz *et al.*, 2009). Liu *et al.*, (2002) and Khurshid *et al.*, (2006) stated the same results that mulching improves the ecological environment of the soil and increases soil water contents.

The vegetative mulch materials derived from fresh residues of Mexican sunflower (*Tithonia diversifolia),* siam weed (*Chromolaena odorata*), elephant grass (*Pennisetum purpurem)* and guinea grass (*Panicum maximum*) applied at 10t/ha on heaps four weeks after planting of yam were effective in improving soil physical properties at Akure and Oba-Ile sites sources. Compared to the control, the materials were effective in increasing soil moisture content significantly at both sites. Mexican sunflower (9.82; 10.07%), siam weed (9.01; 9.16%), elephant grass (7.63; 7.61%), guinea grass (7.42; 8.01%) and control (6.89; 6.93%) respectively. Mexican sunflower and siam weed were most effective in improving soil moisture content. The presence of mulch should have reduced evaporative wastes loss thereby conserving moisture and reducing temperature (Agele ~~et al.~~, 1999a, ~~1999b~~). Also the mulch by protecting the soil should have stabilized the soil structure against raindrop impact (Adeniyan *et al.*, 2008).

Three mulch treatments applied at a rate of 10 t ha^{-1} (straw mulch), 800–850 mm width with 0.009 mm thickness (polythene mulch) and 1 kg ai ha^{-1} mixed in 1000 l ha^{-1} of water (chemical mulch) were compared to an unmulched control, the layer of polythene and grass mulch significantly reduced evaporation from the soil surface. Thus higher moisture content was always observed in the 0–60 cm soil layer of the mulched plots compared to that of the unmulched plots. This moisture difference ranged from 10% one or two days after rainfall to more than 22% over short periods of break in rainfall. These figures indicated that evaporation was high in unmulched plots. The greater soil profile moisture under mulch has important implications on the utilization of water by crop and on soil reactions that control the availability of nutrients and biological nitrogen fixation (Surya *et al.*, 2000). In a growing season, like spring 2001, when early rains are followed by a short-period of drought, the conditions in the top 30 cm of the soil, with respect to the availability of water and nutrients, will determine the survival of the young crop. The study showed that within a period of 10 rainless days, the soil moisture on the surface and the upper subsoil of unmulched plots can be reduced from field capacity to wilting point or below, whereas the soil moisture in the mulched plot will remain well above the wilting range. Cooper (1973) and Adeoye (1984) recorded high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Water vapour flux density in the top 20 cm of the soil with polythene mulch was 1.7 times that of unmulch control, indicating greater movement of water from the deeper layers upward (Hu *et al.*, 1995; Ramakrishna *et al.*, 2006).

Rice husk mulch, cassava bagasse mulch, cassava peel mulch and cassava peel-soil mixture applied at a rate of 30kg m^{-2} on wet basis with height of 2-5 cm and black polyethylene film mulch were studied. Except under rice husk mulch, there were no significant differences in gravitational water increasing in all treatments. The general increase of gravitational water nevertheless showed that soil macro pores also increased in all the treatments, which was probably due to the general decline of bulk density and the increase of water stable aggregates (WSA). In the organic amendment treatments, the differences of macro pores at initial to final stage were bigger at all layers than the other treatments. Among all the organic amendments investigated, the available water content (AWC) decreased or stable in general, except at the surface layer (0-5cm) depth of rice husk mulching (19%) and in the deeper layer (15-25cm) depth of cassava peel-soil mixture treatment (12%.). The increased AWC at surface layer of rice husk mulching is assumed due to the slight SOM increasing. However, the current results show that amending cassava peel by mixing it into soil greatly enhanced the AWC especially at deeper layers (Komariah *et al.*, 2008).

2. 3. 3 Soil Bulk Densities

Surface mulching, earth-banding, stone-barriers and intercropping sorghum with groundnut were compared to a control treatment. In the control, stone-barrier and earth-banded plots, bulk density values show no significant differences among them. In mulched and intercropped plots, which do not differ significantly from each other in the first season, average bulk density values decreased with time in both growing seasons. Mulched plots produced the lowest mean bulk density values (1.57 and 1.56g/cm^3) at a 0.9 m soil depth, followed by intercropped plots in the first and second seasons respectively. There is a decrease of 0.44 and 0.32% and 0.89 and 0.51% in bulk density in surface mulching and sorghum and groundnut intercrop in the first and second seasons respectively as compared with control. In both seasons, soil bulk density is found to decrease and differences are more pronounced in the topsoil (0-15cm) than in the subsoil (30-90cm) depths. In the upper layer of mulched plots, trash incorporation, termite tunneling and other macro faunal activities and probably the slight decomposition of mulching materials and plant roots were considered the main reasons for the significant lower bulk density. These results are in accord with earlier studies conducted by Lal *et al.*, (1980) on tropical Alfisol. Manrique and Jones (1991) have also reported similar observations. It is concluded that, in both growing seasons, mulched and intercropped plots showed the lowest bulk density values at all depths, whereas, control and earth-banded plots showed the reverse (Adam *et al.*, 2009). Under mulch, Lal (1978) reported that, the soil bulk density reduces from 1.70 g/cm^3 to 1.40g/cm^3 at 0-10 cm depth and from 1.70g/cm^3 to 1.42g/cm^3 at 11-12 cm depth of an Oxi Paleusalf soil in Nigeria.

Mulch materials derived from fresh residues of Mexican sunflower (*Tithonia diversifolia)*, siam weed (*Chromolaena odorata*), elephant grass (*Pennisetum purpurem)* and guinea grass (*Panicum maximum*) applied at 10t/ha were effective in improving soil bulk density at Akure and Oba-Ile sites which have high bulk densities of (1.30 and 1.40 gcm^{-3}) respectively for yam yield. Relative to the control (1.38; 1.27gcm^{-3}), the materials reduced the soil bulk densities significantly. Mexican sunflower and siam weed were most effective in reducing soil bulk density because of enhanced biotic activity which led to reduction of soil density. Also the mulch by protecting the soil should have stabilized the soil structure against raindrop impact (Adeniyan *et al.*, 2008). Fergusen and Gumbs (1976) observed that tuber yield of yam was reduced by increased soil bulk density above 1.1gcm^{-3}.

Pervaiz *et al.*, (2009) reported that three mulch levels of wheat straw applied at the rate of 0, 7 and 14Mg ha^{-1} significantly reduced soil bulk density. Higher soil bulk density was observed in control (1.41 Mg m^{-3}), followed by 7 Mg ha^{-1} (1.39 Mg m^{-3}) and minimum in 14Mg ha^{-1} (1.35 Mg m^{-3}). Ghuman and Sur, (2001) concluded that mulching decreases soil bulk density of the surface soil. Rice husk mulch, cassava bagasse mulch, cassava peel mulch and cassava peel-soil mixture applied at a rate of 30kg m^{-2} on wet basis with height of 2-5 cm and black polyethylene film mulch were studied. Compared to the control (1.10 kgm^{-3}), bulk density significantly decreased in rice husk mulch (1.04kgm^{-3}) and cassava bagasse mulch (1.08kgm^{-3}) (Komariah *et al.*, 2008). Applications of organic soil amendments improved some of the physical properties of acid sulfate soil of West Kalimantan. Bulk Density (BD) decreased from 1.24 Mg m^{-3} in the control experiment to 1.14 Mg m^{-3} in the rice straw treated soil (Agusalim, *et al.*, 2010).

2. 3. 4 Soils Organic Matter Content

Organic mulches especially those of low C:N ratio can dramatically impact soil microbial activity and nutrient availability thereby increasing soil fertility and plant growth. Nitrogen and other nutrients are cycled as organic matter is decomposed by soil microbes. Furthermore, the soil is worked continuously by earthworms, insects, and natural weathering processes, which stir the nutrient pool and incorporate decomposing organic matter in a process known as nitrogen mineralization and inorganic forms of nitrogen (ammonium, nitrite, and nitrate) are released from organic matter as it is decomposed (Herms *et al.*, 2001).

Three mulch levels of wheat straw applied at the rate of 0, 7 and 14 Mg ha^{-1} significantly increased soil organic matter at both soil depths. Mean maximum value was observed in 14Mg ha^{-1} (1.32 g kg^{-1}), followed by 7Mg ha^{-1} (0.98 g kg^{-1}) and minimum in contyol (0.65 g kg^{-1}) at 0-15 cm depth. Similarly, mean maximum value was observed in 14 Mg ha^{-1} (0.82 g kg^{-1}), followed by 7Mg ha^{-1} (0.53 g kg^{-1}) and minimum in control (0.40 g kg^{-1}) at 15-30cm depth (Pervaiz *et al.*, 2009).

Rice husk mulch, cassava bagasse mulch, cassava peel mulch, cassava peel-soil mixture and black polyethylene film mulch were compared to control. With exception of rice husk mulching especially at 0-5cm depth, soil organic matter (SOM) significantly decreased in all the soil layers under the various treatments as followed. Control (28 X 10^{-3} kg/kg), cassava peel-soil mixtures (31 X 10^{-3} kg/kg), cassava peel mulch (31 X 10^{-3} kg/kg), cassava bagasse mulch (27 X 10^{-3} kg/kg) and the rice husk much (36 X 10^{-3} kg/kg). Fifteen months after application, the cassava peel-soil mixtures and cassava peel mulch treatments had not undergone decomposition and could be seen physically in its original form with the naked eyes. This indicates that 15 months were probably too short for cassava peel to decompose to contribute to the enhancement of SOM. On the other hand, there was a speedy decomposition of cassava bagasse mulch within a very short period after application. In that case, the decomposed SOM had already been mineralized into nutrients and used by the plants, hence SOM decreased at the end of observation period. In the meantime, 15 months after its application, the rice husk mulch had been partially decomposed with the remaining still covering soil surface. Although insignificant, the partially decomposed rice husk may have slightly increased SOM at the upper layer (0-5cm). It is expected that the remaining rice husks would continue to decompose beyond the 15 months study period to enhance SOM at the sub-layers. According to the period and the rate of decomposition of each organic material and their role in SOM enhancement discussed above, rice husk can be recommended for use as organic amendment with a moderate decomposition rate (Komariah *et al.*, 2008).

2. 3. 5 Soils Nutrient Content

The effect of six treatments: no soil amendment as the control, Rice Straw (15 t ha^{-1}), Rice husk (15 t ha^{-1}), Rice husk ash (10 t ha^{-1}), Rice husk biochar (10 t ha^{-1}) and siam weed (15 t ha^{-1}) on the chemical properties of acid sulfate soil in West Kalimantan were compared. In general, application of organic soil amendments significantly improved the chemical properties of acid sulfate soil. There was an increase in soil cation exchange capacity (CEC) and a decrease in exchangeable Al and soluble Fe. The results also showed that application of organic soil amendments increased the content of P, K and Ca, but did not significantly influence the amount of Mg and Na. The highest CEC, P and K were observed in soil treated with rice husk biochar, but did not significantly differ from that treated with rice husk ash. The increase in CEC of the soil with organic soil amendments would probably be due to the negative charge arising from the carboxyl groups of the organic matter. The increase in CEC with the addition of organic matter has been shown elsewhere (Bot and Benites, 2005). Biochar has a high CEC and with its high recalcitrance Glaser *et al.*, (2002), it is reasonable that soil applied with biochar had the highest CEC. An increase in soil CEC with the application of rice husk biochar has also been shown by (Chan *et al.* 2007). The decrease in exchangeable Al and soluble Fe in rice husk biochar and other organic soil amendments is undoubtedly due to the increase of CEC in the soil. The results showed that exchangeable Al and soluble Fe decrease as CEC increases. The improvement of the soil's physical properties, especially soil aggregation, might also contribute to the lowering of Fe in lowland rice. This soil structure improvement will make the soil condition more oxidative so the solubility of the Fe decreases. The increase in elemental plant nutrients P, K, and Ca is as a result of addition of plant nutrients in the organic soil amendments as has been suggested by (Ponamperuma, 1982). The increase of P nutrient could have also been as a result of increasing the soil pH due to rice husk ash or rice husk biochar application (Agusalim *et al.*, 2010).

Mulch materials derived from fresh residues of Mexican sunflower (*Tithonia diversifolia),* siam weed (*Chromolaena odorata*), elephant grass (*Pennisetum purpurem)* and guinea grass (*Panicum maximum*) applied at 10t/ha were effective in improving soil chemical properties at Akure and Oba-Ile sites. The mulches did not increase soil N, P, Ca and Mg significantly. However, Mexican sunflower and siam weed slightly increased soil N and P at both sites of study. Elephant and guinea grasses also increased soil P slightly at Obaile. But mulches significantly increased exchangeable soil K at both sites relative to the control. At Akure all mulches gave significant increases in soil K, whereas at Obaile only Mexican sunflower and siam weed had significant effect. At both sites the latter treatments mostly enhanced soil K status and siam weed had highest values (Adeniyan *et al.*, 2008).

Five treatments namely: control (no mulch), guinea grass (*Panicum maximum*) mulch, mixture of guinea grass/dadap leaves mulch, dadap leaves (*Erythrina* spp.) mulch, poultry manure mulch applied at 40 kg to each plot of size 5.0 m x 4.0 m were tested on potato grown on a soil in Samoa. The soil is high in organic carbon and total nitrogen, low in potassium and has moderate amount of exchangeable bases (Morrison *et al.,* 1986; Poasa, 1999). In human and livestock nutrition, phosphorus (P) and calcium (Ca) are important macro minerals. P content was more in the petiole portion than in other parts, however, the difference was not significant. Except for the petiole, overall P concentration was lower than the 0.38 g kg^{-1} level suggested as adequate to meet the requirement of the dairy cow but not of beef cattle, goats and sheep. Generally, P concentration is low in Samoa Aregheore and Hunter (1999) and it was assumed that the different mulch materials would improve its distribution and accumulation in the soil and subsequently in the sweet potato tissues. K and Mg concentrations in all parts were also lower than critical levels suggested as adequate for the dairy cow, beef cattle, sheep and goats (NRC, 1980; McDowell, 1985; McDowell *et al.*, 1993). Except in the tubers, the concentration of Ca in other parts was higher than levels suggested by NRC (1980) and McDowell (1985) to meet the requirements of the dairy cow, grazing beef cattle, sheep and goats. This therefore demonstrated that the aerial part of sweet potato contains an appreciable amount of Ca to meet the requirements of ruminant livestock. The influence of type of mulch material on trace mineral concentration of sweet potato showed that, Fe, Mn, Cu and Zn concentrations in different parts were significantly different from each other and type of mulch material seems to have significant influence on their concentrations. The dadap mulch had significantly high concentration of Fe in all parts than other mulch types. The aerial parts of the sweet potato met the Fe, Mn, Cu and Zn requirements of grazing ruminant and humans (FAO/WHO, 1974; NRC, 1980; McDowell, 1985). Ca and Fe concentrations in both the leaves and tubers are higher than levels suggested as adequate by the FAO/WHO (1974) expert group on Ca and Fe requirements for all ages in humans. In conclusion the type of mulch material used had little influence on the distribution and accumulation of available macro-minerals however, they seems to have significant influence on trace mineral concentrations of sweet potato (Aregheore and Tofinga, 2004).

2. 4. EFFECTS OF MULCHES ON GROWTH AND YIELDS OF SOME CROPS

2. 4. 1 Tomato

Four agro industrial wastes applied at 5t ha^{-1} were evaluated. The wastes were brewery spent grain (sorghum based), ground cocoa pod husk (air-dried), rice bran and sawdust and there was a control. Considering the low values of organic matter, N, P, K, and Ca in the slightly acidic soil at the experimental site, the agroindustrial wastes, especially the less carboniferoius spent grain, cocoa husk and rice bran are expected to improve soil fertility and availability of nutrients to tomato plant. It was found that agro wastes enhanced nutrient status of tomato significantly especially in case of N, P, K and Ca. Tomato grown with sawdust with highest: C: N had least value of leaf among the wastes. This is because it would have been most resistant to decomposition and caused microbial immobilization of nutrients especially N leading to depressed plant growth (Olayinka, 1990). Spent grain that had highest N content gave highest leaf N. Spent grain and cocoa pod husk with highest P gave highest leaf P content. Cocoa husk that had highest value of K gave highest leaf K value. The increased availability of nutrients to tomato adduced to application of industrial wastes led to significant increases in growth and yield of tomato as indicated by values of plant height, leaf area, number and weight of fruits. This is especially so in case of spent grain, cocoa husk, and rice bran. Control and sawdust did not increase plant height and number of fruits, although sawdust increased leaf area and fruit weight insignificantly. Therefore, sawdust is not recommended for direct application. Olayinka and Adebayo (1985) had found that incorporation of highly signified sawdust reduced growth and yield of maize and uptake of N and P. Relative to control, spent grain, cocoa husk and rice bran increased fruit weight by 149, 177 and 60% respectively and increase in number of fruit by 67, 77 and 37%. The increases given by spent grain and cocoa husk were statistically similar. This is consistent with similar values of leaf N, P, K, Ca and Mg recorded for the wastes. Rice bran and sawdust with lower values of tomato yield had lower values of leaf N and P. Cocoa husk that gave highest fruit yield also gave highest leaf P and K. These observations highlighted the importance of spent grain and cocoa husk as source of N, P and K (Odedina *et al.*, 2007). Saxena *et al.*, (1975) stated the importance of availability of N, P and K in determining tomato performance.

Four types of mulches such as water hyacinth, straw, amada leaf and Banana leaf and a control (where no mulch was used) were experimentally evaluated on growth of three tomato varieties namely BARI tomato-3, Ratan and BARI tomato-6. The different indigenous mulches exhibited highly significant effect on plant height, number of leaves per plant, leaf area per plant, dry weight of leaves, stem and roots and fruits per plant, at final harvest of tomato. The tallest plant (123.20 cm), highest number of leaves (65.73), greater leaf area (1007.00 cm^2) and maximum dry weight of leaves, stem, roots and fruits per plant were obtained with the plants grown under water hyacinth mulch followed by other mulches such as straw, amada leaf and banana leaf while the control treatment gave the lowest values. Similar opinion was also put forward by Buitellar (1989). Total dry matter (TDM) per plant measured at final harvest was also affected significantly by the water hyacinth mulch which produced the maximum (89.63g) TDM followed by straw mulch while the minimum (57.09g) TDM was obtained in control. A significant variation in the number of flower clusters per plant, fruit per cluster and fruit per plant was observed in different mulching. Water hyacinth mulching produced the highest number of flower clusters per plant and number of fruits per plant followed by straw mulch. The weight of individual fruit was highly significant by different mulches. The maximum individual fruit weight (66.09 g), fruit weight per plant (1.50 g), fruit weight per plot (5.99 g) and fruit yield (59.94 t/ha) was found with the plants grown under water hyacinth mulch followed by straw, amada leaf and banana leaf mulches, while the control showed the lowest performance (Kayum *et al*., 2008).

2. 4. 2 Watermelons

Effects of four treatments: non-mulch control with staking; coconut sawdust mulch, guinea grass mulch, mature coconut fronds, all applied at 20 cm thick on yam growth were evaluated. At the first harvest, fewer but heavier fruits (max 15.1 kg) were picked, whereas the second harvest yielded more but lighter fruits. The watermelon yield ranged from 58.6 to 69.2 t/ha. The results show that there is a significant positive effect of all mulch treatments on fruit yield. There was also a significant effect of sawdust (69.2 t/ha) and grass (68.0 t/ha) mulch on fruit relative to plastic (62.9 t/ha), fronds (63.6 t/ha) mulch and the control (58.6 t/ha). The sawdust and the grass mulch treatments also had a significant effect on the number of fruits per plant. The significant increase in watermelon fruit yield in the mulch treatments was mainly due to the increased number of fruits per plant, and not to the weight per fruit. The results generally correlate with the capability of the mulch to conserve soil moisture, ranking from lowest in the control, to highest in plastic treatment. However, plants under plastic mulch were affected by gummy stem blight disease resulting in lower yield (Manu *et al*., 1995). A number of field trials with positive effects of mulch on different crops (maize, soybean, mungbean, cowpea, papaya) have been reported by (Sekhon and Kaul, 1978; Younge and Plucknett, 1981; Simpson and Gumps, 1986; Mongia, 1991; and Wicks *et al*., 1994). All these authors account for the positive effects of mulch as due to three factors namely conservation of soil moisture, reduction of soil temperature and weed control.

2. 4. 3 Cucumbers

Three mulch treatments: black or clear polyethylene mulch 1.2m wide and 2.5 x 10-2 mm thick lay by hand before planting while grass straw was applied to give a uniform 5cm thick mat. Phosphorus fertilizer was broadcasted at 21kg P_2O_5/ha before transplanting. There was faster increase in plant height and leaf count under clear and black polyethylene mulches compared to straw mulch and bare ground during the early stages of cucumber growth. During the first four weeks of trial 1, black and clear polyethylene mulch ensured faster shoot growth than bare soil and straw mulch. Greater length of exposure to optimum root temperatures under polyethylene mulch probably accounts for increased shoot growth in these treatments early in the season. Greater early vegetative growth of cucumber under these mulches also led to a greater yield than under bare soil. These results support those of Wien *et al*., (1993), who showed that increased tomato growth and yield by polyethylene mulching is a consequence of enhanced root growth and nutrient uptake early in the season. It is probable that high soil temperatures under polyethylene mulch at 5 cm deep in trial 2 would have contributed to the inferior yield of cucumber grown under clear and black polyethylene mulch than with straw (Tindall *et al*., 1991). However, factors other than temperature alone must be addressed to account for the yield enhancement by straw mulch. Yield differences in different cropping times under similar mulch treatments have been attributed to environmental factors such as ambient temperatures, amount of irradiance and soil moisture content (Abdul-Baki and Spence, 1992). These results are in conformity with the findings of Bhella and Kwoleck (1984), where significant increases in plant growth were observed under polyethylene mulch compared to no mulching. The significant difference in plant height and number of leaves among the mulch treatments also support the findings of Hallidri *et al*., (2001) who reported the highest cucumber plant heights and leaf numbers with clear and black polyethylene mulch then straw and the least under unmulched control. In addition the quality of radiation reflected from the mulch may have affected leaf temperature and probably leaf angle (Osiru and Hahn, 1994). This coupled with increased efficiency of nutrient uptake per unit root could have been involved in the mulch induced shoot growth and increased the leaf biomass (Wien *et al*., 1993). The increased plant growth due to mulch was reflected in increased fruit numbers and yields compared to the bare ground treatment in trial 1. Fruit numbers increased significantly due to mulch with increases of between 15 to 27% over unmulched plots being observed. The yield increases in trial 1 were up to 33% higher compared to unmulched plots. The higher yield under mulch was perhaps due to the fact that mulching gave robust plants containing more biomass and leaf surface area thus enhancing carbohydrate production and availing more assimilates needed for fruit filling. Longer fruits were harvested under black and clear polyethylene mulches compared to straw mulched and unmulched plots. In addition, the amount of soluble solids in the fruits was always high when plants were produced under mulch. Cucumber is one of the several plant species that exports stachyose to the fruits (Pharr *et al.*, 1985), thus the soluble solid content was probably due to sugar, an indication that the sweetness of cucumber can be improved by mulching (Gupta and Acharya, 1993). Clearly during periods of cold weather, usually between July to October, mulching with clear polyethylene gives the best overall performance of cucumber in terms of early growth, fruit number, early and total yield as well as fruit length and soluble solid content. Straw and black polyethylene mulches also improve cucumber yield and soluble solid content over no mulch in cold weather. In hot weather conditions, usually between November to February, straw and black polyethylene mulches can significantly increase leaf numbers and give higher yields over clear polyethylene and no mulch treatments (Korir *et al.*, 2006).

2. 4. 4 Maize

Effects of three mulch levels of wheat straw applied at the rate of 0, 7 and 14 Mg ha^{-1} on growth of maize were compared. Mulch affected non-significantly plant height at 45 days, while significantly at 70 days after sowing, where as maximum plant height was obtained in 14 Mg ha^{-1} (2.53 m), followed by 7 Mg ha^{-1} (2.45 m) and minimum in control (2.40 m). Similar trend in plant height was observed at harvest. Wicks *et al.*, (1994) and Khurshid *et al.*, (2006) pointed out that maize grew taller under greater mulch levels, because of availability of more soil moisture contents for plant growth. The biological yield was increased significantly by increasing mulch levels, maximum biological yield was observed in 14 Mg ha^{-1} (19.8 Mg ha^{-1}), followed by 7 Mg ha^{-1} (18.7 Mg ha^{-1}) and minimum in control (18.2 Mg ha^{-1}). Mulch significantly increased grain yield. Maximum grain yield was observed in 14 Mg ha^{-1} (10.5 Mg ha^{-1}), followed by 7 Mg ha^{-1} (9.4 Mg ha^{-1}) and minimum in control (8.6 Mg ha^{-1}) (Pervaiz *et al.*, 2009). Tolk *et al.*, (1999) and Liu *et al.*, (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots and subsequently leads to higher grain yield.

Five levels of organic mulch (0, 2, 4, 6 and 8t/ha) made up of Ganba grass *(Andropogom gayanus* Kunth var. gayanus) were investigated on a hybrid maize (*Zea mays* L.) variety *Oba super* 2. The grass was harvested and oven dried at 70°C to a constant weight before applying to plots a week after crop emergence. The tallest plants were obtained with the highest (8t/ha) followed by the 6 t/ha mulch rate that produced significantly taller plants than the others in both years and at all sampling periods. The 0 t/ha rate at all sampling periods in the two seasons produced the shortest plants. The number of leaves per plant was maximized also at 8 t/ha mulch rate in all sampling periods in both seasons while the control produced the least. Weight of grains per cob obtained in 6 and 8 t/ha mulch rates across the seasons were statistically higher than other mulch rates. The least weight of grains/cob occurred in the control in both seasons. The total grain yield produced in 2 and 4 t/ha mulch rates were statistically similar but lower than those obtained in 6 and 8 t/ha rates which however, had similar grain yield, but all the mulched plots had higher grain yields than the control in both seasons. Across the seasons, the 6 and 8 t/ha rates produced more than twice the total grain yield obtained from the unmulched control plots. When averaged over the two seasons, increases in mulch rates from 0 to 2 t/ha increased grain yield by 61%, further increased to 4 t/ha increased yield by 87.5% while a further increase to 6 t/ha brought about an increase in yield of 155.6%. A much further increased to 8 t/ha however, resulted in only a negligible increase of 7.8% in grain yield. It appears that the 6t/ha rate emerged a better choice than 8t/ha probably due to the phenomenon of decreasing returns. These results are consistent with those of Lal (1974), Lal (1978), IITA (1983), Wicks *et al.*, (1994) and Lal (1995) who reported that early maize growth was retarded by higher mulch levels as a result of reduced soil temperature but maize grew taller and faster under greater mulch levels subsequently due to increased soil moisture and adequate temperature which stimulated root development and growth. These results are also in consonance with IITA (1983), Bhatt *et al.*, (2004) and Khurshid *et al.*, (2006) that mulching with crop residue at the rate of 4 and 6 t/ha not only affected both physical and chemical properties of the soil but also maintained good grain yield. The difference in growth and yield attributes observed between the mulched and unmulched plots may be attributed to the higher soil moisture reserves in the mulched plots since higher soil moisture is known to enhance efficient use of fertilizer while the excellent solar radiation during the growth seasons encouraged higher photosynthetic rates which culminated in the higher yields obtained (Uwah and Iwo, 2011).

2. 4. 5 Sorghum

Six land configuration and wood-chips mulch treatments: flat bed (FB), open ridge (OR), tied ridge (TR), FB + mulch (FBM), OR + mulch (ORM) and TR + much (TRM) were evaluated from 1999 - 2002 on a sandy loam soil, northeast Nigeria for their effects on growth, leaf nutrient composition and straw yield of sorghum. The mulched (FBM, ORM and TRM) treatments also produced the highest grain yield in all the four experimental years (Chiroma *et al.*, 2006c). The increase in grain yield associated with straw production was greatest in 2000, where each unit increase in straw production increased grain yield by 0.45 kg ha^{-1}. It is evident from the results of this study that combining the practice of flat seed bed cultivation or ridge tillage with mulching using wood-chips can promote better growth and yield (grain and straw) of sorghum. The superior growth and yield response by the plants grown in the mulch treated plots was a consequence of cumulative effect of improvement in soil physical environment as evidenced by low bulk density and penetration resistance Chiroma *et al.*, (2006b) and greater storage of rain water in the soil profile Chiroma *et al.*, (2006c) thus creating a favourable environment for crop growth. Furthermore, improvement in the fertility of the surface 0 - 0.075 m layers of the mulch treated plots Chiroma *et al.*, (2005) may have also influenced the growth and straw yield of sorghum. This was in line with the findings of a study conducted on a similar soil and under similar climatic conditions (Selvaraju *et al.*, 1999). However, differences in straw yield between FB, OR and TR treatments were always small and insignificant except for 1999 when TR treatment significantly out yielded the FB treatment by about 64% (Chiroma *et al.*, 2006).

2. 4. 6 Groundnut

The performance of groundnut under three mulch treatments applied at a rate of: straw mulch (10 t ha^{-1}), polythene mulch (800–850 mm width with 0.009 mm thickness) and chemical mulch (1 kg ai ha^{-1} mixed in 1000 l ha^{-1} of water) were evaluated. Observations on plant growth showed that the groundnut plants in polythene and straw mulched plots were generally tall, more vigorous and reached 50% flowering 4–6 days earlier than in the unmulched plots. The more favorable soil environment under the polythene and straw mulch, especially during the early part of the growing season, resulted in increased number of pods per plant, pod mass, test weight and striking pod and stover yield increases. Devi Dayal *et al.*, (1991) observed early flowering (by 5 days) in mulch treated groundnut crop. Hu *et al.*, (1995) also reported increased crop growth (3.2–4.0 cm), dry root mass (12.2–50.1%), nitrogen-fixing activity (3.3–128.7%), chlorophyll content of the fresh leaves (41–78%) and more reproductive buds (63.3–94.1%) in polythene mulched plots than unmulched plots and thereby advanced peak flowering stage by 9 days. Grass mulch increased grain yield by 15–22% in maize and by about 10% in millet in northern Guinea and Sudan savanna regions of Nigeria (Adeoye, 1984). Cheong *et al.*, (1995) observed highly positive correlation of proportion of sound seeds, 100-seed weight and shelling ratio with seed yield of groundnut and recorded 3.21 t ha^{-1} with clear polythene, 2.99 t ha^{-1} with black polythene and 2.31 t ha^{-1} without mulch in Iri. Choi and Chung (1997) recorded more flowers, pegs, pods and kernels and greater 100-kernal mass in polythene mulched plots than on the unmulched plots in Suwon, Korea. Park *et al.*, (1996) recorded seed yield increase in soybean by 18% with transparent film and by 15% with black film. The total dry matter (t ha^{-1}) of groundnut recorded in both autumn and spring were as followed: control (5.38; 5.84), straw mulch (5.88; 6.40), polyethylene mulch (6.32; 6.88) and chemical mulch (6.14; 6.10) respectively. Use of straw as mulch provides a more attractive option for farmers. The key factors that make straw mulch attractive are low cost (US$ 9.6 ha^{-1} as against US$ 94.5 ha^{-1} for polythene mulch and US$ 25 ha^{-1} for chemical mulch) and ease in availability and application (Ramakrishna *et al.*, 2006).

2. 4. 7 Yam

Mulch materials derived from fresh residues of Mexican sunflower (*Tithonia diversifolia),* siam weed (*Chromolaena odorata*), elephant grass (*Pennisetum purpurem)* and guinea grass (*Panicum maximum*) applied at 10t/ha at Akure and Oba-ile sites in rainforest zone of Southwest Nigeria were studied. All mulches increased tuber weight significantly, Mexican sunflower (2.1; 2.3 kg), siam weed (2.2; 2.2 kg), elephant grass (1.7; 1.8 kg), guinea grass (1.7; 1.9 kg) and control (1.3; 1.4 kg) at Akure and Obale respectively. Increased performance of yam due to mulches can be adduced to improved availability of K in soil, reduced soil temperature, reduced soil bulk density and enhanced soil moisture content especially in case of Mexican sunflower and siam weed with mean soil moisture content close to 10%. Variation in soil moisture content between 10 to 32% and soil temperature between 25 to 30 ^{0}C were found suitable for yam growth (Ohiri, 1995). At both sites, the latter treatments mostly enhanced soil K status and siam weed had highest values. This finding is noted since yam has high requirement for K (Obigbesan, 1981, 1999). Hence the relatively high tuber weights recorded for sunflower and siam weed can be adduced partly to higher K status of their soils (Adeniyan *et al.*, 2008). Yam tuber growth and yield are known to reduce with increase in soil bulk density above 1.1g/cm3 (Fergusen and Gumbs, 1976). The uptake of N, P, K, Ca and Mg by yam has been found to reduce with increased soil bulk density (Agbede and Ojeniyi, 2003).

The following treatments, ridge (mulched and unmulched), mound (mulched and unmulched) and zero (mulched and unmulched) were studied. Mulched treatment recorded higher number of tubers (396) followed by partially mulched (382) and the least was unmulched treatment (327). Although the number of tubers harvested per plot counts in yield evaluation, the best parameter as earlier noted is the weight of the tubers since it is directly related to the size of the tuber and the cost of any yam tuber is determined more by its size, length and weight (Eborge, 2002; Oamen, 2004). For this reason, the tubers were weighed and the result showed that partially mulched had the highest tuber yield (10.3 t ha^{-1}) followed by unmulched (8.1 t ha^{-1}) and mulched treatment (7.4 t ha^{-1}). The higher yield in partially mulched treatment is as a result of better soil microclimatic management. The mulch might have improved the soil condition for well-developed roots than unmulched treatments (Okoh, 2004). The removal of the mulch during the tuber formation stage increased the soil temperature, a condition needed for the development of long and big tubers (Madu, 2003). This improved thermal condition during the tuber stage resulted in higher yield than the mulched treatment, which suppressed the temperature. This is in contrast with the results of Maduakor *et al.*, (1984) and Halugalle *et al.*, (1985), who ascertained that higher yam tuber yield is associated with mulched than unmulched treatment. The mean yield for this study is 8.6 t ha^{-1}, which is lower than the (9.4-14 t ha^{-1}) recorded in Haiti and Ghana by Sergio (2001) and Adamasi (2006) respectively. It is also lower than the 10.7 t ha^{-1} of Nigeria's and 9.2 t ha^{-1} of World's average yield (Song, 2003; Onwueme and Sinha, 1999). The lower yield observed in this study could be attributed to the fact that fertilizers were not used, while the studies with higher yield cited above applied fertilizers (Odjugo, 2008).

2. 4. 8 Potato

Two varieties of early potatoes Finka and Katka evaluated under grass mulch applied on ridges in different terms (grass mulch after planting – GM1 and grass mulch after second hoeing – GM2). As grass mulch, 25 mm high layer of chopped grass was applied (GM1 – 1st and 16th day after planting, GM2 – 14th and 21st day after planting). A control treatment (bare soil) was used for comparison. The results showed that the yield was influenced mostly by mulching (55.9 %), then by variety (39.2 %) and by growth structure (4.9 %). In comparison with control variant (bare soil=120.5), grass mulching increased significantly the total number of tubers per plot in both terms of mulch application, however, markedly higher number of tubers per plot was found in GM1 (191.6) followed by GM2 (160.3). The results also proved the positive effect of grass mulch and a term of its application on the yield of ware potatoes, where a significantly higher yield of ware potatoes were found in GM1 (34.7t/ha), followed by GM2 (30.2t/ha) and control variant (bare soil=25.4t/ha). Grass mulch and a term of its application also influenced the size proportionality of tubers under the hill. In both variants with grass mulch, higher number and weight of tubers under hill in the size fraction 55-60 mm and in the fraction over 60 mm were measured than in control variant. However, in GM1, the number and the weight of tubers under hill in mentioned fractions were the highest from all variants. The results of the experiment again proved the effect of grass mulch and a term of its application on the parameters of inner quality of tubers. In comparison with control variant (bare soil), GM1 had a positive effect on ascorbic acid content (higher by 8.7 %), chlorogenic acid (higher by 17.2 %) and glycoalkaloids content (lower by 6.2 %) on average of tested varieties (Dvorak *et al.*, 2009).

Four treatments were tested in 2006 and 2008: one application of mulch at planting time, one application at emergence time, two applications of mulch (at planting and emergence time, and control (no mulch). The mulch consisted of rice dry straw spread to form a uniform layer over the soil at the rate of 9 t ha^{-1}. In each trial, the different treatment factors (mulch and plant density) did not significantly affect tuber number per plant or per tuber size category. The average tuber number per plant varied from five to eight tubers per plant. This is in agreement with earlier findings of seven tubers per plant in the same region using eight genotypes for three years. Fresh or dry tuber yields for each trial did not differ significantly between treatments for the two factors (density and mulch). Nevertheless, fresh or dry tuber yield tended to increase when mulch was used or when the spacing interval between rows was decreased. The average fresh tuber yield in the mulch trials ranged from 4.1 (± 0.9) t ha^{-1} for Victoria cultivar to 10 (± 1.6) t ha^{-1} for clone 388611.22. To our knowledge, these yields have never been reached before in potato experiments conducted previously in the lowlands of Burundi. The mean dry matter concentration per trial varied from one season or location to the other. In 2006 (mulch trial), the mean tuber dry matter concentration was 16.5% at Mparambo against 20.3% at Mugerero using Victoria in both sites. In the trials conducted at Mparambo in 2008, the tubers of clone 388611.22 from the mulch trial contained 17% of dry matter at harvest time. These variations of the overall means per trial may be attributed to the confounding effects of genotypes, years (water stress, weeds) and locations (soil) that prevailed during the respective trials. It is already known that water stress can raise dry matter concentration by up to 2% (of increase) in field trials (Lahlou *et al.*, 2003). Normally, consumer potato tubers contain at least 18% dry matter (Woolfe, 1987). On average, a HI of 0.56 (±0.044) was obtained for the mulch trial and the difference between trials is difficult to interpret due to confounding effects of differences in genotypes (Victoria cultivar and clone 388611.22) and crop management (mulch and density) (Harahagazwe *et al.*, 2010).

Five treatments namely: control (no mulch), guinea grass (*Panicum maximum*) mulch, mixture of guinea grass/dadap leaves mulch, dadap leaves (*Erythrina* spp.) mulch, poultry manure mulch applied at 40 kg to each plot of size 5.0 m x 4.0 m were tested. Sulifoa (2001) reported that the different mulch materials (guinea grass, guinea grass/dadap, dadap and poultry manure) had no effect on yield and other yield related characteristics of sweet potato. However, the number of leaves and secondary vines obtained at the harvest time in 4 months were more in two of the mulch materials. The type of mulch had significant effect on crude protein (CP) content of the leaf portion of the sweet potato. The leaves had a mean CP value of 26.2±3.32% and this value was similar to that reported by Devendra and Gohl (1970; FAO (1989) and Orodho *et al.*, (1993) for sweet potato leaves grown in other tropical environment. Crude fibre (CF) content was higher in the stems and petioles, however, the type of mulch material had no effects on its contents in different parts of sweet potato. Ether extract (EE) content was slightly different among the parts and the type of mulch material seems to have some influence but the differences observed were not significant. Ash content was higher in the petioles, leaves and whole plant than in the stems and tubers. The CF, EE and ash contents of the sweet potato investigated in this trial are similar to values reported by Oyenuga (1968) and Gohl (1981) for sweet potato grown in West Africa and in West Indies. Type of mulch material had no significant influence on CP and GE contents of sweet potato tuber. The CP content of sweet potato tubers reported in this trial was relatively high compared to other tropical tuber crops such as yams and cassava. In conclusion the type of mulch material used had little influence on the distribution and accumulation of available nutrients concentrations of sweet potato tubers (Aregheore and Tofinga, 2004).

2. 4. 9 Cassava and sweet potato

Three mulches, namely, rice straw (C: N ratio 51.5), grass (*Panicum maximum*, C: N ratio 36.2) leaves and legume (*Gliricidia sepium*, C: N ratio 20.6) leaves were applied to the plots at a rate of 4 kg of fresh material per square meter. A treatment without mulch was maintained for comparison. Mulches increased leaf area and crop growth rates and reduced the time for tuber initiation significantly in both cassava and sweet potato. This implied the benefits of using some type of plant material as mulch for promoting the vegetative growth and tuber initiation of these tropical crops. The leaf area indices of cassava and sweet potato were increased by the legume leaf mulch (21% in cassava and 10% in sweet potato) when compared to the non-mulched plants. The benefits of using a nitrogen rich cover crop, in terms of LAI and CGR, were thus greater in the long-aged cassava plants. The increased leaf area promoted the crop growth rates of both species significantly, over that of plants grown without mulch (Yamauchi *et al.*, 1996). The legume leaves enhanced dry matter accumulation to a greater extent than the other two mulches (16% in both species) and a significant correlation existed between leaf area indices and crop growth rates for both species. Mulches enhanced mean time for tuber initiation significantly in both species (Cassava by 23 and sweet potato by 18 days). The legume mulch enhanced tuber initiation to a greater extent in both species (30 days in cassava and 18 days in sweet potato), while the grass mulch reduced the time for tuber initiation than rice straw. This impact could be related to leaf area development and growth rates, as greater photosynthetic efficiency and crop growth lead to earlier tuber initiation in tuber crops (Oswald *et al.*, 1994). The better growth of the shoots could again be related to the nitrogen supply of the rapidly decaying legume leaves in contrast to the slower decomposition of grass and straw. The benefits of these two mulches could be attributed to retention of soil moisture and lower temperatures in the soil (Ayanaba and

Okigbo, 1975). Yields of tuber crops are increased by early tuber initiation (Walworth and Carling, 2002). The yield components and yields of both species were enhanced by various mulches. The mean increases in tuber numbers of cassava and sweet potato due to mulching were 67% and 33% respectively, highlighting the greater impact in cassava, the long aged crop. The impact of the legume mulch was also greater in cassava (22%) than in sweet potato (6%). Mulches increased the marketable tubers compared to no mulches but the type of mulch had no significant effect on the percentage marketable tubers. This suggested that the carbohydrate distribution in the tubers is not affected by mulches, while mulches increase the process of development of all tubers. Application of a mulch increased mean tuber yields of cassava and sweet potato by 62% and 41%, respectively. This implied the greater benefits of the mulch on the long aged cassava which could be subjected to changes in the environment for a longer period of time than the short aged sweet potato. However, while the different mulches had no impact on sweet potato yield, the grass or a straw mulch increased tuber yields of cassava by 23%. This was somewhat unexpected result, as legume leaves can provide nitrogen, which could affect yields. The benefits of the rice straw or grass mulch could accrue to its slower breakdown, thus providing better soil moisture conservation for a longer period of time, and also by reducing soil temperatures, affecting tuber bulking in tropical tuber crops (Ossom *et a*l., 2001). Due to greater yields obtained by mulching, harvest indices of both species were increased. In contrast, the harvest indices were not significantly affected by the three mulches used (Sangakkara *et al*., (2004).

CHAPTER THREE

3. 0 MATERIAS AND METHODS

3. 1. Experimental site

The experiment was carried out at Plantation section of the Department of Crop and Soil Sciences of Faculty of Agriculture of Kwame Nkrumah University of Science and Technology (K.N.U.S.T.), which lies on latitude 06^{O} 41' N, longitude 01^{O} 33' W and altitude 261.4m. The soil belongs to Kumasi series of tropical rain forest developed over Plinthi Ferric Acrisol (FAO/UNESCO, 1990).

The climate of the study area exhibits the characteristics of a tropical climate with annual maximum and minimum mean soil temperatures of 31.91^{O}C and 21.76^{O}C respectively. The rainfall pattern is of double peak with mean annual rainfall of 116.99 mm. While the annual mean relative humidity at 0900 and 1500 hours are 84.3% and 60.0% respectively. The annual mean sunshine is 5.33 hours for the past ten years (2002-2011) according to information from the meteorological agency (K.N.U.S.T. 2012). The site used for the experiment has been used previously to grow maize.

3. 2 Experimental materials.

The cassava varieties used were Afisiafi, Dokuduade, Ampong, Essan and Debor, (land race). They were obtained from Crop Research Institute (CRI) at Fumesua near Kumasi. These varieties used in the experiments were chosen on the basis of their resistance to most of the cassava pests and diseases, their preferences for high starch content and local uses. The mulch materials used were rice straw, rice husk, guinea grass, cocoa pods and puerraria residues. There was also a control treatment (without mulch). The experiment was a 5x6 factorial arranged in a randomized complete block design with 3 replications per treatment.

3. 3 Land preparation and planting

The land was ploughed and harrowed after which it was divided into 3 blocks. One replication contained 30 plots each measured 3m× 5m and separated from each other by 1.5m. Cassava cuttings of length between 15cm to 20cm were planted on flat surface on 28 October, 2010 at a spacing of 1m x 1m. The mulch materials were applied one month after planting on 26 November, 2010 at a rate of 2kg/plant (20t/ha). The mulch was applied in ring about 20cm from each plant at a thickness of 2cm. The timing of the mulching was to avoid harming of the cuttings and the sprouts. Each plot contained 15 plants and data was taken on the 5 middle plants.

3. 4 Mulch materials and soil sampling

Samples of ground mulch materials and soil samples at the experimental site taken from 0-15cm depth before planting were bulked together for chemical analysis in the Soil Science laboratory and the following parameters were determined.

3. 4. 1 Soil texture

Soil texture was determined using the hydrometer method. Soil was digested with hydrogen peroxide and dispersed in 5% sodium hexametaphosphate solution and one or more drops of amyl alcohol or methanol 95% added and gently swirled to minimize foaming. The content was transferred to a 1000 ml sedimentation cylinder and water added for sedimentation. The first Hydrometer reading after 40 seconds and the first temperature reading with the help of a thermometer were taken. The samples were undisturbed for 3 hours and the second hydrometer and temperature readings were taken (Bouyoucos, 1962).

Calculations:

% Sand =100 - $[H_1+0.2(T_1-20) - 2] \times 2$

% Clay = $[H_2 + 0.2(T_2 -20) - 2] \times 2$

% Silt = 100- (% Sand + % Clay)

Where:

H_1= 1st Hydrometer reading at 40 seconds

T_1= 1st Temperature reading at 40 seconds

H_2= 2nd Hydrometer reading at 3 hours

T_2= 2nd Temperature reading at 3 hours

-2 = Salt correction to be added to hydrometer reading

0.2(T-20) = Temperature correction to be added to hydrometer reading.

T= degrees Celsius

3. 4. 2 Soil pH

Soil pH was determined using a soil : water ratio of 1: 2.5 technique by a standard pH meter in the laboratory. 10g of air-dried soil was weighed into a 100 ml beaker and 25 ml distilled water added. The suspension was stirred vigorously for the next 20 minutes and allowed to stand for about 30 minutes by which time most of the suspended clay would have settled out from the suspension. The pH meter was calibrated at pH of 4, the electrode of the pH meter was inserted into the partly settled suspension and the pH value read off (Rhoades, 1982).

3. 4. 3 Percentage nitrogen (N) in the soil and the mulch materials

Determination of total nitrogen (N) in plant and soil samples was done using Kjeldahl method. After digestion of the sample using a Kjeldahl oxidation, an aliquot of 5ml (for plant material), but 10ml (for soil sample) solution was distilled in 10 ml of 40% NaOH and 5ml of 1% boric acid containing 4 drops of the mixed indicator. N/70 HCl (for plant), but N/140HCl (for soils) distillates were removed and titrated until indicator changes from green trough grey to a definite pink. A blank determination was run by digesting reagent blanks in place of the samples (Anderson and Ingram, 1989; Lindner and Harly, 1942).

Calculation

% N in mulch materials = $\frac{\text{corrected ml of N/70 HCl} \times 0.2}{\text{weight of sample taken}}$

% N in soil sample = $\frac{\text{corrected ml of N/140 HCl} \times 0.1}{\text{weight of sample taken}}$

Where: Corrected ml of HCl = titre value of sample – blank titre value

3. 4. 4 Percentage phosphorus (P) in the soil and the mulch materials

After digestion of the sample using Kjeldahl oxidation method, the total P in the soil or plant sample was determined using the pH Adjustment Method. 10ml of the wet-ashed digest solution pipetted into a 50ml volumetric flask, 0.2 ml of 0.5% p-nitrophinol indicator solution added and made just alkaline (yellow colour) with 6N NH_3 solution. Dilute 1N HNO3 added until just colourless. Now 5ml ammonium molybdate / ammonium vanadate mixed reagent added and made to 50 ml with distilled water. The amount of phosphorus present in the solution read off from a calibration curve (Okalebo, 1985).

Calculation

Taken a 10 ml digest aliquot (pH Adjustment technique) for 50 ml final dilution used for colour intensity (absorbance) measurement:

% P in the soil sample/ mulch materials = $\frac{c \times 0.025}{\text{weight of sample taken}}$

Where:

c = corrected concentration for sample solution (in ppm P).

Corrected concentration for sample solution = titre value of sample – blank titre value.

3. 4. 5 Exchangeable potassium (K) in the soil

Determination of exchangeable potassium (K) in the soil was done using flame photometry technique. Soil was extracted with100ml of 1M ammonium acetate (NH_4OAc) solution (pH=7) and filtered through No 42 Whatman paper. 5ml of the soil extract solution pipetted into a 50ml volumetric flask, 1ml of 26.8% lanthanum chloride solution added and the contents diluted to the mark with 1M NH_4OAc extraction solution. This solution was sprayed into the flame of the flame photometer for the determination of K (Osborne, 1973).

Calculation

$$\% \text{ Potassium (K)} = \text{graph reading} \times 10 = \text{mg K}/100\text{g air} - \text{dried soil}$$

3. 4. 6 Exchangeable potassium (K) in the mulch materials

Exchangeable potassium (K) in plant tissues was determined using Kjeldahl procedure followed by spectrometric analysis. 2ml of the wet digested sample solution was pipetted into a 50ml volumetric flask, made to mark with distilled water and mixed well. Sample solutions were sprayed directly into the flame photometer and the amount of potassium present in the solution (c) read off from the calibration curve (Novosamsky *et al.*, 1983).

Calculation

For a 2.0 ml of aliquot of the digest sample solution:

$$\% \text{ K in sample} = \frac{c \times 0.125}{\text{weight of sample taken}}$$

Where:

c = corrected concentration for sample solution (in ppm P).

Corrected concentration for sample solution = titre value of sample – blank titre value

3. 4. 7 Organic carbons in the soil and the mulch materials

Determination of organic carbon was done using Walkey and Black procedure. 2.0 g of sample weighed out into a 500 ml Erlenmeyer flask and exactly 10 ml of 1.0 N Potassium dichromate solution added from a burette, followed by 20 ml of conc. H_2SO_4. The mixture swirled to ensure that the solution was in contact with all the particles of the sample. Flask and content were allowed to cool on an asbestos sheet for 30 minutes. 200 ml (or 1.0 ml) of diphenylamine indicator added and titrated with 1.0 N ferrous sulphate solution until the colour changes to blue and then to a green end-point. The titre value recorded and corrected for the blank solution ($\geq$ 10.5) Nelson and Sommers, (1975).

Calculation

$$\% \text{ Organic C} = \frac{\text{Blank} - (T \times N) \times 0.3}{\text{wt of soil}}$$

Where:

Blank = Titre value for the blank (≥ 10.5)

T = ml of $FeSO_4$ used for the titration (titre value)

N = Normality of $FeSO_4$

Hence:

% organic matter (O. M) = % organic C × 1.724

3. 5 Cultural practices

Weeding was done three times using hoe. No disease and pest control was done.

3. 6 Data Collection

Measurement of soil temperature, soil moisture and soil bulk density were carried out on the soils under the 5 middle plants. Soil moisture and soil bulk density were measured in every four week for 4 sampling occasions but soil temperature was measured weekly for 6 weeks.

3. 6. 1 Soil temperature

Soil temperature was measured at 5cm depth three times, at 9am, 12pm and 3pm using soil thermometers on each occasion. The thermometers were inserted into the soil under the mulch materials in the case of mulch experiments and into the bare soil in the case of the control experiments and the thermometer readings recorded when the mercury settled.

3. 6. 2 Percentage soil moisture

The percentage soil moisture content was determined using the gravimetric method. Moisture cans were used to take soil samples at depth of 5cm from each plot. The soil samples were taken to the laboratory and the wet weight of each soil sample together with its container determined using electronic balance. The soil samples were then oven dried at 105°C for 72 hours to a constant weight, removed from the oven and the dry weight determined after which the soil was poured off and the container weighed using electronic balance (Blake and Hartge, 1982).

Calculation

% Soil Moisture by weight (Mw) = $100 - (\frac{W3 - W1}{W2 - W1} \times 100)$

Where:

W_1= Weight of empty can

W_2= Weight of can + fresh soil

W_3=Weight of can + oven-dried soil

3. 6. 3 Soil bulk density

The soil bulk density was determined using the metal core sampler method or soil fills method. The core sampler was driven into the soil at depth of 5cm with the aid of a mallet. Soil at both ends of tube was trimmed and the end flushed with a straight-edge knife. The core sampler with its content was dried in the oven at 105°C for 72 hours to a constant weight, removed from oven at the end of the period, allowed to cool and the weight of core sampler with its content recorded. Volume of core cylinder was determined by measuring its height and radius (Uhland, 1950).

Calculation

Dry Bulk Density ρ (gcm^3) = $\frac{W2 - W1}{V}$

Where:

W_1 = Weight of empty core cylinder

W_2 = Weight of core cylinder + oven–dried soil

V = Volume of core cylinder ($\pi r^2 h$)

r = radius of the core cylinder.

h = height of the core cylinder.

3. 7 Plant parameters

3. 7. 1 Plant height

The plant height was measured from the ground level along the main stem to the tip of the longest branch using a tape measure. The heights of the five middle plants were measured and the average height calculated. It was measured in every four week for four occasions.

3. 8 Harvest parameters

Harvest was done on November, 2011 (12 months after planting). The five middle plants from each plot were carefully removed and harvest parameters estimated.

3. 8. 1 Number of tubers per plot harvested

All the tubers of the five harvested plants were counted and average value calculated.

3. 8. 2 Fresh weight of tubers per plot harvested

All the tubers of the five harvested plants were cleaned from soil particles, bulked together in a sac and weighed on a hanging scale after which average value was calculated.

3. 8. 3 Plant top weight per plot harvested

The top weight (stems and leaves) of the five harvested plants were bulked together, tied and weighed using a hanging scale and the average value calculated.

3. 8. 4 Total biomass per plot harvested

The total biomass of the five harvested plants was estimated by adding the top weight and tuber weight of the five harvested plants and average value estimated.

3. 8. 5 Tuber yield

An area of $5m^2$ was harvested from each plot for fresh tuber yield assessment. The yield of fresh tubers was computed as below and expressed in tons per hectare (tons ha^{-1}).

$$\text{Yield } (t\ h^{-1}) = \frac{10{,}000 \times \text{weight of tuber from harvested area}}{1000 \times \text{area harvested}}$$

3. 8. 6 Harvest Index (HI)

Harvest index was computed as below and expressed in percentage (%).

$$\text{Harvest index (HI)} = \left(\frac{\text{root weight}}{\text{total plant weight}}\right) \times 100$$

3. 9 Tuber quality

3. 9. 1 Percentage dry matter

The percentage dry matter (DM) was determined from a random bulk sample 1-2 cassava tubers from each harvested plot. Duplicate samples of 200g of fresh tuber slices were taken and dried at $105^{O}C$ for 48 hours in an air-drying oven to a constant weight.

$$\text{Hence \% DM} = \left(\frac{\text{dry weight}}{\text{fresh weight of sample taken}}\right) \times 100$$

3. 9. 2 Percentage starch content

Percentage starch content was estimated using gravimetric method. Five kilograms (5kg) of cassava tubers from each plot were weighed in air and then weighed in water and the percentage starch value read on a calibrated scale.

3. 10 Data analysis

All data was analysed using the analysis of variance technique. Genstat Computer package was used to analysed the data collected. Treatment differences were determined using the Least Significant Difference at 5% probability.

CHAPTER FOUR

4. 0 RESULTS

4. 1 CHEMICAL ANALYSIS OF MULCH MATERIAL AND SOIL SAMPLES RESULTS

The results of chemical analysis of mulch materials and soil samples and detailed weather data at the experimental site before the experiment are presented in appendix 1, 2 and 3 respectively.

4. 2 MEAN SOIL TEMPERATURE

Table 4.1: Effect of cassava variety and mulch type on soil temperature measured on 3 sampling occasions

Treatment	Mean soil temperature (°C)		
	9am	12pm	3pm
Variety			
Afisiafi	28.92	30.93	33.09
Ampong	26.09	28.33	28.86
Debor	28.34	31.38	32.30
Dokuduade	27.97	29.79	30.54
Essan	28.84	30.36	31.19
LSD(0.05)	0.64	0.64	1.07
Mulch materials			
Control	28.09	30.43	31.97
Cocoa Pod Husk	27.95	30.17	31.41
Guinea Grass	27.89	30.06	30.90
Puereria	27.69	30.14	31.31
Rice Husk	28.05	29.69	30.65
Rice Straw	28.52	30.46	30.94
LSD(0.05)	0.70	NS	1.18
CV(%)	3.4	3.2	5.2

There were significant differences in soil temperature under the varieties throughout the three periods of measurement (Table 4.1). Ampong had the lowest morning, noon and afternoon soil temperature of 26.09, 28.33 and 28.86^{O}C respectively which were significantly lower than all other treatments effects. Soil temperature under Afisiafi, Debor and Essan varieties were highest during the morning, noon and afternoon sampling periods respectively.

On the mulch materials, pueraria had the lowest morning soil temperature (27.69 ^{O}C). There was a significant difference between pueraria and the rice straw mulch only. All other treatment differences were not significant. Treatment differences at noon were not significant ($p>0.05$). Soil temperature at 3pm was highest under the control treatment and this was significantly higher than the rice husk mulch only (Table 4.1).

4. 3 PERCENTAGE MEAN SOIL MOISTURE CONTENT

Soil moisture content under the cassava varieties and the mulch treatments are presented in (Table 4.2). At the first sampling, varietal differences were not significant ($p>0.05$). During the second sampling, soil moisture under Essan was the greatest and this was significantly higher than Dokuduade only. Varietal difference at the third sampling was not significant. At the fourth sampling, effect under Ampong variety was the greatest, which was significantly higher than all other treatment effect except Afisiafi.

Mulch materials effects on soil moisture content are presented in (Table 4.2). At all sampling occasions, soil moisture under the control treatment recorded the lowest value. At the first sampling, the control treatment effect was significantly lower than all other treatment effects except under pueraria mulch. Other treatment differences were not significant. At the second sampling, the control treatment effect was significantly lower than all other treatment effects. At the third sampling, soil moisture measured under the cocoa pod husk was significantly higher than that of the control treatment only. At the fourth sampling, however, treatment differences were not significant.

Table 4.2: Effect of cassava variety and mulch type on soil moisture measured on 4 sampling occasions

Treatment	Mean soil moisture content (%)			
	1st Sampling (82 DAP)	2rd Sampling (103 DAP)	3rd Samping (124 DAP)	4th Sampling (135DAP)
Variety				
Afisiafi	6.89	8.00	15.12	15.50
Ampong	6.76	8.15	14.63	16.24
Debor	6.63	7.51	14.07	14.15
Dokuduade	5.97	7.18	14.17	14.55
Essan	6.71	8.20	14.42	15.16
LSD(0.05)	NS	0.92	NS	1.39
Mulch Material				
Control	5.35	6.63	13.42	14.83
Cocoa Pod	6.69	7.95	15.35	15.47
Guinea Grass	6.95	7.78	14.69	15.35
Puereria	6.45	7.91	14.43	15.12
Rice Husk	7.06	8.36	14.27	14.69
Rice Straw	7.05	8.23	14.73	15.27
LSD(0.05)	1.15	1.01	1.45	NS
CV(%)	23.8	17.6	13.7	13.8

4. 4 SOIL BULK DENSITY

The effects of varieties and mulch materials on the soil bulk density are presented in (Table 4.3). On all sampling occasions, the soil bulk density was not significantly affected by the cassava variety. Soil bulk densities were significantly ($p<0.05$) affected by the mulch materials during the first and fourth sampling occasions only. At the first sampling, bulk densities of soil under the control and rice husk mulches were significantly higher than all other treatments. On the fourth sampling day, the treatment effect of the Guinea grass, which was the lowest (1.27gcm^{-3}), was significantly lower than that of the rice husk treatment effect only. All other treatments had similar effects.

Table 4.3: Effect of cassava variety and mulch type on soil bulk density measured on 4 sampling occasions

Treatment	Mean soil bulk density (g/cm^3)			
	1st Sampling (82 DAP)	2rd Sampling (103 DAP)	3rd Sampling (124 DAP)	4th Sampling (135 DAP)
Variety				
Afisiafi	1.39	1.33	1.43	1.36
Ampong	1.37	1.33	1.45	1.36
Debor	1.39	1.39	1.46	1.39
Dokuduade	1.37	1.40	1.40	1.33
Essan	1.37	1.38	1.44	1.40
LSD(0.05)	NS	NS	NS	NS
Mulch material				
Control	1.43	1.40	1.48	1.40
Cocoa Pod	1.34	1.34	1.43	1.37
Guinea Grass	1.35	1.36	1.42	1.27
Puereria	1.34	1.39	1.42	1.31
Rice Husk	1.42	1.36	1.43	1.44
Rice Straw	1.39	1.35	1.45	1.40
LSD(0.05)	0.06	NS	NS	0.08
CV(%)	6.2	7.4	6.4	8.2

4. 5. PLANT HEIGHT

Plant height was affected significantly by the type of cassava varieties (Table 4.4). Debor produced the tallest plants (167.58, 190.61, 212.39 and 245.85cm) respectively, throughout the four measurements. Ampong had the lowest plant height (114.89, 135.51 and 155.91cm) from the first to third measurements respectively and Afisiafi had the lowest plant height (192.10cm) in the fourth measurement. On all sampling days, plant height of Debor was significantly higher than those of all other treatments. Plant heights were not significantly affected by mulch materials on all 4 sampling occasions (p>0.05).

Table 4.4: Effect of cassava variety and mulch type on plant height measured on 4 sampling occasions

Treatment	Mean plant height (cm)			
	1st Sampling (84 DAP)	2nd Sampling (105 DAP)	3rd Sampling (126 DAP)	4th Sampling (147 DAP)
Variety				
Afisiafi	127.2	143.5	158.7	192.1
Ampong	114.9	135.5	155.9	192.5
Debor	167.6	190.6	212.4	245.6
Dokuduade	152.7	175.1	197.6	233.2
Essan	132.5	152.1	172.3	204.1
LSD(0.05)	11.7	12.3	13.1	14.2
Mulch material				
Control	139.8	160.3	179.4	213.2
Cocoa pod	134.1	154.3	174.3	210.2
Guinea grass	142.3	162.5	182.5	217.3
Pueraria	141.4	162.6	184.0	220.1
Rice husk	137.7	157.5	177.2	210.0
Rice straw	138.7	159.0	178.9	211.7
LSD(0.05)	NS	NS	NS	NS
CV(%)	12.6	11.6	10.9	10.0

4. 6 TUBER NUMBER, TUBER WEIGHT AND PLANT TOP WEIGHT

Table 4.5: Effect of cassava variety and mulch type on tuber number, tuber weight and plant top weight of 5 cassava varieties.

	Harvest Parameters		
Treatment	Average tuber number/plant	Average tuber weight (kg/m^2)	Average plant top weight (kg/plant)
Variety			
Afisiafi	7.89	5.70	6.54
Ampong	7.67	7.91	7.15
Debor	8.83	5.55	5.04
Dokuduade	8.00	5.66	7.76
Essan	8.33	8.23	7.59
LSD(0.05)	1.03	1.02	1.31
Mulch material			
Control	8.27	6.06	5.65
Cocoa pod	8.33	6.58	6.86
Guinea grass	7.93	6.31	6.76
Pueraria	8.20	6.71	7.04
Rice husk	7.87	7.26	7.24
Rice straw	8.27	6.73	6.97
LSD(0.05)	NS	1.12	1.44
CV(%)	18.9	23.1	28.8

Debor had the greatest tuber number of 8.83 which was significantly ($p<0.05$) higher than Ampong only. All other treatment effects were statistically similar (Table 4.5). Different mulching materials did not significantly ($p>0.05$) affect cassava tuber numbers.

The average tuber weight was significant among the varieties. Essan had the greatest average tuber weight of 8.23kg per stand and this was significantly higher than all other treatment, except Ampong. The varieties Afisiafi, Debor and Dokuduade produced similar tuber weight. For the mulch treatments, the greatest effect was measured in the Rice husk mulch which was significantly higher than that of the control only (Table 4.5). All other treatment differences were not significant.

Differences in plant top weight among the varieties were significant. Debor produced the lowest average plant top weight of 5.04kg which was significantly lower than all other treatments effect (Table 4.5). The averages top weight from the control treatment was the least and this was significantly ($p>0.05$) lower than that of the Rice husk mulch only. All other treatments did not show any significant effect.

4.7 STARCH CONTENT, DRY MATTER CONTENT, FRESH TUBER YIELD AND HARVEST INDEX

Both variety and mulching materials did not significantly affect cassava starch content (Table 4.6). Debor gave the highest dry matter of 39.17% which was significantly higher ($p<0.05$) than the treatment effects of Afisiafi and Ampong only. Other treatment effects were statistically similar (Table 4.6). The lowest dry matter production among the mulch treatments was measured in the control treatment but this was significantly lower than those of cocoa pod and rice husk mulches only. All other treatment effects were similar.

The varieties affected significantly the fresh tuber yield. Essan had the highest fresh tuber yield of 82.26t/ha which was significantly higher ($p<0.05$) than those of Afisiafi, Debor and Dokuduade. Fresh tuber yield of Ampong was also significantly higher than those of the other varieties except Essan (Table 4.6). The fresh tuber yield was significantly affected by mulch materials. The greatest tuber yield was produced from the rice husk mulch treatment, but this was significantly higher than the control treatment effect only.

The highest dry matter content under mulch treatment was recorded by cocoa pod which was significantly higher ($p<0.05$) than the control treatment only (Table 4.6).

The harvest index was significantly affected by the cassava varieties. Dokuduade produced the lowest harvest index but this was similar to that of Afisiafi. However, the treatment effect of either variety was significantly lower than those of Ampong, Debor and Essan varieties. Cassava harvest index was not significantly ($p>0.05$) affected by mulch materials (Table 4.6).

Table 4.6: Effect of cassava variety and mulch type on starch content, dry matter content, yield and harvest index of 5 cassava varieties

Treatment	Tuber Quality		Harvest Parameters	
	Starch Content (%)	Dry Matter Content (%)	Yield (t/ha)	Harvest index (%)
Variety				
Afisiafi	27.11	36.48	56.98	46.57
Ampong	27.08	36.60	78.62	52.53
Debor	26.95	39.17	56.04	53.35
Dokuduade	27.44	37.41	56.64	42.21
Essan	27.51	37.18	82.26	52.05
LSD(0.05)	NS	2.09	10.05	3.89
Mulch material				
Control	26.73	35.38	61.39	51.04
Cocoa pod	27.24	38.58	65.69	48.55
Guinea grass	26.92	37.37	62.56	48.04
Pueraria	27.72	37.27	67.17	48.97
Rice husk	27.32	37.95	72.56	50.15
Rice straw	27.39	37.64	67.28	49.31
LSD(0.05)	NS	2.29	11.01	NS
CV (%)	9.6	8.4	22.8	11.8

CHAPTER FIVE

5. 0 DISCUSSIONS

5. 1 MEAN SOIL TEMPERATURE

The lowest mean soil temperature under Ampong and Dokuduade might be due to their dense canopy structures observed at the time of measurement which might protected the soil from excessive heat penetration hence, the lowest temperature. The higher mean soil temperature recorded under Afisiafi and Debor might due to their canopy structures which might allowed the rays of the sun to penetrate the soil. This condition might have increased the amount of heat that entered the soil to increase the soil temperature. Leaf inclination has been considered almost entirely in terms light distribution in the canopy (Duncan, 1971; Augus *et al.*, (1972).

Apart from the control, all mulch treatments had a decreased in the morning, noon and afternoon temperatures. However, the high mean soil temperature under rice straw mulch recorded for morning was similar to the results of Choi and Chung (1997) who observed that thermisters placed at the soil surface recorded increase in soil temperatures by 2.8-9.4^{O}C and 0.9-7.3^{O}C at 5cm depth. The high soil temperature recorded under the rice straw mulch in this experiment might due to the light nature of this material that might have helped easy penetration of the sun's rays to the soil causing high soil temperature.

The lower soil temperature recorded under the mulch materials was due to the fact that mulch material provided good cover of the soil and hence prevented the rays of sun from heating the soil to increase its temperature. Presence of mulch materials reduced evaporative waste loss thereby reducing the soil temperature (Agele *et al.*, 1999a; 1999b). A difference of 2-7^{O}C between mulched and unmulched plots during the early planting season was observed in western Nigeria (Olasantan, 1999). The afternoon (12–16 hr) temperatures measured at 5cm depth under mulches were considerably lower (31-33 ^{O}C) than those of the bare soil temperatures (32-37 ^{O}C) above 35 ^{O}C (Brady and Well, 1996).

The high afternoon soil temperature recorded in the control treatment (bare soil) was due to direct exposure of this soil to the rays of the sun. This condition could cause heating of the soil and therefore, high mean soil temperature. Song (2003) observed that even at 20cm depth, supra-optimum soil temperature conditions were noticed in unmulched treatments in the months of March (36.1°C) and April (35.4°C).

5. 2 PERCENTAGE MEAN SOIL MOISTURE CONTENT

The high percentage moisture content observed under Ampong through the four sampling periods could be attributed to the fact that this variety produced denser canopy covers that prevented evaporative loss of moisture from soils under this variety. Also the positions of the leaves of this variety may be such that any dew that fell on it dripped directly to the soil, hence the increase in the soil moisture content.

The lower percent moisture content recorded in the control experiment in all the four sampling periods was due to direct exposure of the soil to the rays of sun which increased evaporative loss of moisture. Moisture could also be lost from the bare soil by surface run-off thereby decreasing infiltration capacity during rainfall (Odjugo, 2008).

The mulch materials increased the percentage moisture content especially in the first and second sampling periods, rice husk (1.71% and 1.73%), rice straw (1.70% and 1.60%), guinea grass (1.60% and 1.15%), cocoa pod (1.34% and 1.32%) and pueraria (1.10% and 1.28%) respectively. When a soil is mulched, crusting, which clogs soil pores and reduces the infiltration of water is diminished. The higher moisture content obtained in the organic mulches compared to the control could be due to the fact that the organic mulches prevented evaporation of water. The organic mulches could also increase the water-holding capacity of soil by increasing their organic matter content as they decompose. Cooper (1973) and Adeoye (1984) recorded high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Liu *et al*., (2002) and Khurshid *et al*., (2006) stated that mulching improves the ecological environment of the soil and increases soil water content.

5. 3 SOIL BULK DENSITY

The cassava varieties did not affect the soil bulk density in all the four measurements even though there were some differences among the values obtained. The soil bulk density values remained almost the same in the first and second measurements but the values increased in the third measurement and then reduced again in the fourth measurement. The reduction in the soil bulk density in the 4th sampling period might be due to proliferation of the roots of the cassava varieties and decaying of plant debris and trashes. This inference agreed with the results of Hulugalle and Rodridquez (1988) in which the type of seeds mainly affected soil physical properties. The pulverization and disturbance of the soil surface during land preparation, weeding and deposition of plant debris and trashes, plant root proliferation and decaying could aid in reducing the soil bulk density and increasing the porosity of the top soil (0-15cm) depth (Adam *et al*., 2009).

Relative to the control, the soil bulk density significantly decreased under cocoa pod and pueraria mulches by $0.09 g/cm^3$ each, under Guinea grass by $0.08 g/cm^3$ in the first measurement and by $0.13 g/cm^3$ and $0.09 g/cm^3$ in Guinea grass and pueraria respectively in the fourth measurement. However, despite insignificant values of bulk density in the second and third measurements and in other treatments (rice husk and rice straw mulches) in the first and fourth measurements the values generally decreased under the mulch treatments. In the upper layer of mulched plots, trash incorporation, termite tunneling and other macro faunal (earthworms, ants, etc.) activities and probably the slight decomposition of mulching material and plant roots (tubers) were considered the main reasons for the significant lower bulk density (Lal *et al*., 1980). Manrique and Jones (1991) and Komariah *et al*., (2008) have also reported similar observations.

Again, the mulches by protecting the soil should have stabilized the soil structure against raindrops impact (Adeniyan *et al*., 2008), heat from the sun energy and prevented compacting of the soil hence the decreased in bulk density under the mulch treatments. Mulching reduces the caking of soils caused by the high absorption of heat or solar radiation (Orkwor *et al*., 1998). Under mulch, Lal (1978) reported that, the soil bulk density reduced from $1.70 g/cm^3$ to $1.40 g/cm^3$ at 0-10 cm depth and from $1.70 g/cm^3$ to $1.42 g/cm^3$ at 11-12 cm depth of an Oxi Paleusalf soil in Nigeria. Cocoa pod, pueraria and guinea grass were most effective in reducing soil bulk density because better environment existed under the mulch materials which enhanced soil micro and macro organisms to work on the soil which might led to reduction of soil bulk density.

5. 4 PLANT HEIGHT

The cassava varieties showed significant differences in plant height in all the four sampling occasions. Debor had the tallest plant height in all the four sampling occasions. The differences in plant height are due to genotype of the varieties used. Cassava cultivars are differentiated by characteristics such as branching habit, height, colour of stem, etc (Tweneboah, 2000).

The mulch materials did not affect the plant height significantly even though there were some differences among the values obtained. The general increase in plant height under mulch materials might be due to availability soil moisture, reduced soil temperature and lower soil bulk density under them. The insignificant plant height values under the mulch materials compared to the control could be due to less quantity of the mulch materials applied. Wicks *et al.*, (1994) and Khurshid *et al.*, (2006) had reported that maize grew taller under greater mulch levels because of availability of more soil moisture contents for plant growth. Pervaiz *et al.*, (2009) observed that mulch materials affected non-significantly plant height at 45 days, while significantly at 70 days after sowing, where as maximum plant height was obtained in 14 Mg ha^{-1} (2.53m), followed by 7 Mg ha^{-1} (2.45m) and minimum in control (2.40m). Uwah and Iwo (2011) reported that maize plant grew tallest under 8t/ha mulch rate, followed by the 6 t/ha that produced significantly taller plants than the others in both years and at all sampling periods but the 0 t/ha rate at all sampling periods in the two seasons produced the shortest plants.

5. 5 AVERAGE TUBER NUMBER, TUBER WEIGHT AND PLANT TOP WEIGHT

The mulch materials did not affect the tuber number, although with the stable environment observed under the mulch materials, one was expecting more roots to develop into tubers. Harahagazwe *et al.*, (2007) found that, different treatment factors (mulch and plant density) did not significantly affect tuber number per plant or per tuber size category of potato. Manu *et al.*, (1995) also stated that, there was no significant treatment effect on the number of yam tubers per plant.

The slight differences in average tuber weight among the varieties might due to genotypic differences. Ampong, Essan and Dokuduade varieties had vigorous growth structures with about 4-8 branches thus expanding the source size for better tuber growth. Dvorak *et al.*, (2009) stated that yield of potato was influenced mostly by variety (39.2 %) and by growth structure (4.9 %). Although the number of tubers harvested per plot counts in yield evaluation, the best parameter as earlier noted is the weight of the tubers since it is directly related to the size of the tuber and the cost of any yam tuber is determined more by its size, length and weight (Eborge, 2002; Oamen, 2004).

Compared to the control, the average tuber weights recorded under the mulch materials were higher. The higher tuber weight was due to bigger tuber size recorded under these mulch materials which was due to good soil structure, stable soil moisture content reduced soil temperature and lower soil bulk density recorded under the mulch materials. Mulch and time of its application influenced the size proportionality of tubers and higher tuber weight in the size fraction 55- 60 mm and in the fraction over 60 mm were measured than in control (Dvorak *et al.*, 2009). Hu *et al.*, (1995) also reported increased dry root mass (12.2–50.1%) of groundnut in mulched plots than unmulched plots. Mulching improves soil condition for well-developed roots than unmulched treatments (Okoh, 2004).

Again, the bigger tuber size obtained in this trial might be the results of improved nutrient and organic matter levels as the organic materials decompose. A relatively high tuber weights recorded for sunflower and siam weed was adduced partly to higher K status of their soils (Adeniyan *et al.*, 2008). Moisture distribution in the upper soil layer is more uniform in mulched soil compared to unmulched soil which results in more roots being developed in the upper soil layer which usually is richer in nutrient and useful micro-organisms (Lippert *et al.*, 1964; Knavel and Mohr, 1967).

The statistically significant differences in plant top weight among the cassava varieties were basically due to differences in the genotype among them. The higher plant top weight observed in Dokuduade, Essan and Ampong varieties was as a result of a lot of branches (4-8) they produced. Debor and Afisiafi had the lowest plant top weight due to few branches (2-3) observed in these varieties at the time of harvest.

The increase in top weight under some of the mulch materials when compared to the control was due to better growth of shoot which could be related to maintenance of stable soil environment (high moisture content, reduced temperature, good soil structure, etc) under the mulch materials. Ramakrishna *et al.*, (2006) observed that groundnut plants in mulched plots grew more vigorous and reached 50% flowering in 4-6 days earlier than in the unmulched plots. The better growth of shoot could again be related to the nitrogen supply of the decaying organic mulches (Ayanaba and Okigbo, 1975).

5. 6 PERCENTAGE STARCH CONTENT, DRY MATTER CONTENT, FRESH TUBER YIELD AND HARVEST INDEX

Both treatments (variety and mulch) did not affect the starch content significantly. The insignificant differences in these values might be that the starch content of tubers (cassava) depends mostly on the genotype used and a mere application of mulch materials cannot cause much change in the starch yield (content). Sangakkara *et al.*, (2004) found that the carbohydrate distribution in the tubers is not affected by mulches, while mulches increase the process of development of all tubers.

The dry matter content did not vary significantly among the varieties except Debor which has significantly higher dry matter content values compared to other varieties. Variations of the overall mean dry matter may be attributed to the confounding effects of genotypes, years (water stress, weeds) and locations (soil) that prevailed during the respective trials (Harahagazwe *et al.*, 2007). The use of local materials and the advanced materials from CIAT/Colombia, accomplished a significant upgrading (50%) of dry root yield of the breeding population. Of this process, enhanced biomass (25%) and root dry matter content (15%) were the major factors (CIAT, 1993, 1995; Kawano, 1998; Kawano *et al.*, 1987; 1998).

Moreover, the differences in the dry matter values could be attributed to canopy structure, leaf positions on the plant, rate of photosynthesis which is also affected by leaf area index. The amount of leaf area available during tuber bulking period largely determines tuber yield in yam (Chapman, 1965; Enyi, 1972a, 1972b). The higher yield from the white surface plastic mulch was related to higher LAI and longer LAD which ensured higher bulking rate for a longer period (Osiru and Hahn, 1994).

The mulch materials increased dry matter content compared to the control even though the values were insignificant. The increase performance in the dry matter under mulch treatments could be assigned to better soil environment under the mulch materials which might enhance early tuber initiation. Early yam tuber initiation (12-13 weeks after emergence) allow for sufficient leaf area development before tuber bulking begins (Sabulo, 1972; Onwueme, 1978).

The cocoa pod treatment enhanced dry matter accumulation to a greater extent than the other mulch materials (38.58%) which might due to high content of K in cocoa pod. This observation is true because tuber crops (cassava, yam) have high requirement for K (Obigbesan, 1981, 1999). Soil nutritional requirements of cassava per unit dry matter yield are much lower than most of other crops, except for potassium (Howeler, 1991, 1995, 2001; Howeler *et al*., 2000). The high nutrient absorption by cassava especially of potassium is a result of the crop's high productivity under sub-optimal conditions (CIAT, 2001). Odedina *et al*., (2007) stated that cocoa husk that gave highest fruit yield also gave highest leaf P and K and concluded that the observation highlighted the importance of cocoa husk as source of N, P and K.

Essan and Ampong had the highest yield values which were significant compared to other cassava varieties. The higher yield values obtained in these varieties were shown in their growth structures. They produced vigorous growth structures that consequently resulted into higher yield compared to other cassava varieties.

The mulch materials did not affect the yield significantly except the rice husk mulch. Even though insignificant, the other mulch materials had higher yield values compared to the yield recorded under the control treatment. The higher yield under mulch treatments might be due to early tuber formation because of better soil conditions under these materials. Yields of tuber crops are increased by early tuber initiation (Walworth and Carling, 2002).

Increased performance of cassava under mulches in this trial could be adduced to reduced soil temperature, reduced soil bulk density, improved availability of nutrients in the soil and enhanced soil moisture content. Adeniyan *et al*., (2008) observed that increased performance of yam due to mulches can be adduced to reduced soil temperature, reduced soil bulk density and enhanced soil moisture. Maduakor *et al*., (1984) and Halugalle *et al*., (1985) observed that higher yam tuber yield in mulched treatments was as a result of better soil microclimatic management. Variation in soil moisture content between 10 to 32% and soil temperature between 25 to 30 ^{0}C were found suitable for yam growth (Ohiri, 1995). Application of mulch increased mean tuber yields of cassava and sweet potato by 62% and 41% respectively and this showed greater benefits of the mulch on the long aged cassava which could be subjected to changes in the environment for a longer period of time than the short aged sweet potato (Sangakkara *et al.*, 2004). Tolk *et al.*, (1999) and Liu *et al.*, (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots which subsequently leads to higher grain yield.

CHAPTER SIX

6 .0 CONCLUSIONS AND RECOMMENDATIONS

6. 1 CONCLUSIONS

The results of this study revealed that, soil water and soil temperature regimes were altered by the mulching materials at a depth of 0-5cm. Crop growth was affected by alterations in these regimes, resulting in differences in plant productivities. Mulches were found to improve topsoil moisture content, decreased soil temperatures and soil bulk density when compared to the control treatment. The improvement in the soil's physical properties due to organic mulch applications resulted in the improvement of the growth of the cassava varieties.

The study has also shown that organic mulches have the potential of improving nutrients level of the soil especially K availability which is important for cassava bulking. Cocoa pod husk had the highest K content and it gave the highest dry matter content.

The tuber weight of the cassava varieties were also enhanced by various mulches and this was translated into tuber yield as the rice husk mulch produced the greatest tuber weight and tuber yield.

The yield data presented showed that among the various mulch materials applied, the rice husk produced the greatest tuber weight and tuber yield, hence this can be recommended to farmers upon further studies. Additionally, rice husk mulch caused greatest reduction in soil temperature and soil bulk density and increased soil moisture content.

6. 2 RECOMMENDATIONS

It is recommended that the research work be repeated to ascertain the results before the technology is passed on to farmers. I also suggest that different levels of potassium and rice husk be combined and used as treatments to validate their effects on the growth and yield of cassava.

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APPENDICE

Appendix 1: Chemical properties of the mulch materials before application

Mulch sample	Organic C (%)	Organic M (%)	Total N (%)	Available P (%)	Exchangeable K (%)
Rice Straw	33.12	57.10	1.82	0.23	0.56
Rice Husk	29.93	51.60	1.12	0.18	0.35
Guinea Grass	35.91	61.91	1.26	0.15	1.13
Cocoa Pod	25.54	44.03	2.03	0.22	2.52
Puereria	34.71	59.84	2.66	0.22	1.53

Appendix 2: Chemical properties of the soil at the experimental site before planting

Characteristics of soil sample	Values
Sand (%)	82.56
Silt (%)	11.84
Clay (%)	5.6
Texture	Loamy sand
Ph	4.95
Total N (%)	0.18
Available P (%)	4.37
Exchangeable K (%)	0.17
Organic C (%)	1.42
Organic M (%)	2.44

Appendix 3: Annual average weather data at the experimental site

Years	Mean Annual Values of Weather Elements					
	Rainfall (mm)	Temperature (^{O}C)		Relative Humidity (%)		Sunshine Duration (hrs)
		Max.	Min.	0900	1500	
2002	135.6	32.0	21.4	84	60	5.8
2003	114.4	31.9	21.4	83	59	6.0
2004	102.7	31.5	21.5	85	61	5.3
2005	086.4	31.9	21.3	83	60	5.3
2006	090.7	32.0	21.5	85	57	5.6
2007	166.6	32.2	21.6	84	59	5.2
2008	096.7	32.0	21.8	81	60	5.0
2009	120.5	31.9	22.6	86	62	4.8
2010	116.4	32.1	22.5	87	62	5.1
2011	139.9	31.6	22.0	85	60	5.2

Source: Ghana Meteorological Agency, K.N.U.S.T., (2012).