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GROWTH, YIELD AND QUALITY OF CASSAVA AS INFLUENCED BY TERRAMEND 21, POULTRY MANURE AND INORGANIC FERTILIZER.

BY

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APRIL, 2009

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BY

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BSc. Agriculture

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DECLARATION

I hereby declare that this research work presented in this thesis is my own work and that, to the best of my knowledge, it contains no material previously published by another person for the award of a degree in any other University, except where acknowledgement has been made in the text

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Date	Date

ABSTRACT

The effects of Terramend 21(TM 21), poultry manure and inorganic fertilizer on the growth, yield and quality (cooking and starch) of two cassava varieties were studied at the Plantation section of the Kwame Nkrumah University of Science and Technology, Kumasi. The experimental design was a split-plot with four replications. The main plots consisted of the two cassava varieties (Nkabom and IFAD), while the five soil amendments were assigned to the subplots. The five soil amendments were: Terramend 21 at the rate of 250ml/ha, NPK applied at the rate of 60 – 40 – 40 kg/ha, TM21 at the rate of 250ml/ha + NPK at 30-20-20kg/ha, poultry manure at the rate of 4t/ha and no soil amendment as the control. TM 21 is a biostimulant and soil rejuvenator.

The response variables were: plant height, fresh shoot weight, number of tubers/plant, tuber mean weight, tuber dry matter, tuber yield, harvest index, cooking quality and starch content. Normal husbandry practices such as weed control and application of soil amendments were under-taken and harvesting was done at 12 months after planning.

Results showed the presence of micro-organisms in all the treatments. Fertilizer treatment gave the highest number of colonies (35) and fertilizer with TM 21 gave the lowest value (13). Terramend 21 treatment did not contain *Aspergillus niger* and *Fusarium* sp, but contained the highest number of unidentified microorganism colonies. Plant height increased steadily from three months after planting (MAP) to 10 (MAP) for the two varieties. IFAD recorded greater height than Nkabom at all the sampling periods except at 3 (MAP). Fresh shoot weight was significantly different between the varieties and the soil amendments. There was a significant interaction ($P< 0.05$) between the varieties and soil amendments in tuber yield. The highest tuber yield (46.9t/ha) was produced by a combination of TM21 and Fertilizer application in Nkabom. Poultry manure produced the highest yield of 46.8t/ha in IFAD. The harvest index did not differ between the two varieties but was significant ($P<0.05$) with soil amendment application. Results showed no significant interaction between the varieties and the soil amendments in dry matter content. Starch content ranged from 25.1 % to 25.7% in Nkabom and 24.2% to 26.9% for IFAD, and was not significantly different between the two varieties. No significant effect ($P>0.05$) was observed in tuber cooking quality between the varieties and soil amendments. The results showed a positive correlation between tuber dry matter and starch content, tuber mean weight and tuber yield, tuber dry matter content and tuber yield. A negative correlation existed between number of tubers/plant and tuber mean weight. Cassava producers should use soil amendment application to increase cassava tuber yields. The results have also shown that the mealiness of cassava tubers is not negatively affected by the application of soil amendments in the production of cassava.

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DEDICATION

To my mother, Madam Konu Adoa

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CHAPTER ONE INTRODUCTION

Cassava (*Manihot esculenta*, *Crantz*) belongs to the family Euphorbiacea. It is believed to have been introduced into Africa by the Portuguese from Latin America in the 16th century (Nweke *et al*, 1994). In the West Coast of Africa, cassava is as important as yam and a staple food after rice (Nkweke *et al*,1994). The crop is also important in the farming systems of most African countries because it produces tuberous roots under the most adverse conditions and is able to produce tuberous roots throughout the year.

In Ghana, cassava is a staple and an export crop and contributes 16% to the Agricultural Gross Domestic Product (Safo-Kantanka, 2004). The crop is exported mainly in the form of chips and starch for industrial use. The products are used for the production of industrial alcohol, cosmetics, and pharmaceuticals and in the textile industry (IITA, 1990). The nutritional value of the storage roots is mainly caloric even though it contains a lot of water, fibre, ash and protein. The leaves contain about 30% protein by dry weight and are eaten in some parts of Africa as a vegetable. The crop is therefore an important staple food in Sub-Saharan Africa and accounts for a third of all staple foods produced (FAO, 1986). The FAO, (1999) also reported that cassava serves as food for over three hundred million people living in Latin America.

Cassava cultivation in Africa is mainly in the humid tropical regions. In Ghana, it is cultivated in almost all the six agro ecological zones mostly by peasant farmers. It can be cultivated as a sole crop but mostly it is grown as an intercrop in association with other crops like maize, plantain, cocoyam and cowpea.

In spite of the important role this crop plays in Ghana and it is reported to be the baseline for food security as the crop still faces several constraints (Arku and Kelly, 2001). The major problems include diseases and pests, poor soils, poor management practices, weed infestation, poor markets and easy perishability of products.

According to Nweke (1996) cassava has the potential to bridge the food gab in Africa but yields are generally low because of the low fertility status of the soils on which cassava is grown.The root yield of cassava in Ghana is low falling between 5.0 and 11.8t/ha though cassava has the potential to yield up to 30t/ha (MOFA, 2001). This low yield is due to diseases and pests and the low soil fertility status of most of the soils on which cassava is grown. The low soil fertility has been accelerated by;

Removal of nutrients from the soil during crop harvest, erosion and leaching and failure to add soil amendments through crop residue, manures and fertilizers (Quansah *et al*, 1997)

Because cassava can produce better on degraded soils than most crops, much attention is not given to its fertilization.

The application of soil amendments to sustain high yields in cassava production should be an obvious choice. But the use of fertilizers for cassava production is not a common practice in Ghana. A survey carried out by Tetteh and Frimpong (1991) came out with reasons why cassava producers in Ghana do not apply fertilizer to cassava. These reasons include the perception that

(i) cassava does not require fertilizer, (ii) the cassava root tubers rot when fertilizer is applied and

(iii) the food quality of cassava root tuber is reduced when fertilizer is applied.

In Africa relatively few fertilizer trials have been conducted on cassava because very few farmers apply fertilizer to the crop (Okugun *et al*, 1999). Cassava plants do not readily translocate nutrients from lower to upper leaves when plant nutrients are not adequate as other plants do and nutrient deficiency symptoms are not pronounced as in other crops. However, work done by FAO (1996) on

the use of fertilizer on the crop has shown that the crop is responsive to fertilizer application just like any other crop. Increase in root tuber yield up to 45% in West Africa has been reported by Krochman and Samuels (1970) as a result of the application of
fertilizer.

High premium is given to agricultural products produced organically especially by the advanced countries. There is, therefore, need to research into technologies which can improve the soil for high crop yields without the addition of agroinorganics. One of such technologies is the technology of effective microorganism which enhances the value of organic matter in the soil.

Terramend 21 (TM21) is one of such technologies. TM 21 is completely biological and a soil rejuvenator. It is a preparation made up of water, *Bacillus megaterium, Bacillus subtlis,*
Pseudomonas fluorescents, Saccharomyces cerevisiae and may also contain *Bacillus pumilus, Lactobacillus paracasei* and minerals such as calcium, sodium, potassium, magnesium, molybdenum, copper, iron and boron (Best, 2004). TM 21 is reported to feed and increase microbial population resulting in better soil condition and higher crop yield. It is also reported to improve soil aggregation by the production of polysaccharides and reduces the leaching of inorganic fertilizers for better plant use. It also makes the plant more tolerable to pests, diseases and adverse weather conditions (Best, 2004).

In spite of the prospects offered by TM 21 and other soil amendments to sustain the production of cassava in Ghana, the crop has been cultivated largely on marginal soils resulting in low yields. If the problems of low soil fertility and disease and pests are adequately addressed in cassava cultivation, it is envisaged that the productivity of cassava will be improved resulting in higher income for cassava farmers.

The objectives of this study was therefore, (i) to determine the effect of TM 21, poultry manure and fertilizer on the growth and yield of two cultivars of cassava and (ii) to determine the effect of soil amendments on the quality(cooking and starch) of cassava tubers

CHAPTER TWO LITERATURE REVIEW

2.1 Origin and Botany

Uncertainty shrouds the botanical origin of cassava as it has been generally believed that it had no known wild ancestry or progenitor outside the cultivated species (Rogers and Appan, 1973).Furthermore, it has been argued that the crop evolved through indiscriminate introgression involving a dozen of wild relatives with the genus *Manihot*. In contrast Allem (2002) reported that a wild population of *Manihot* similar to the cultivated species was found in Goias in Central Brazil.

Allem (2002) therefore presented a hypothesis for the geographical origin of cassava because most of the biological diversity of the genus *Manihot* occurs in central Brazil. He, therefore, concluded that the cassava originated from Brazil from where it found it's way to Africa by the Portuguese.

Cassava is a perennial shrub of the family euphobiaceae. It can reach a height of 1-4m and it is cultivated mainly for its starch roots. Cassava can be propagated by stem or seed but it is usually propagated by stem. Seed propagation is usually done in breeding programmes and this takes a longer time to establish. The cassava plant has a symbodial branching. The main stem may divide 1 to 4 producing secondary branches that produce other successive branching.

Plants propagated from seed have a typical primary root system developed similar to a dicotyledonous species. The radical of the germinating seed grows vertically downwards and develops into a tap root from which adventitious roots originate. Later the tap root and some of the adventitious roots develop into storage roots.

Plants grown from stem cuttings have adventitious roots that arise from the basal root surfaces and occasionally from the buds under the soil. These roots develop into fibrous root system and only a few of them (3-6) bulk and become storage root

2.2 Climate and Soil requirements

Cassava is grown over a wide range of edaphic and climatic conditions between latitude 30^0 north and 30^0 south. It is grown in regions from sea level up to an altitude of 2300m mostly on soils considered to be marginal for the production of other crops. However, cassava grows well in many soil types ranging from light to heavy but for better root development, deep well drained, friable sandy loam to loamy soils are ideal. When planted on sandy soils, measures should be put in place to minimize soil erosion. The soil should also contain some amount of organic matter and with a depth of 30-40 cm. Because Cassava requires a well drained soil, the clay content of the soil should be less than 18 % and with a pH range of 6-7. This is because the crop does not tolerate saline conditions. But for best performances the crop requires a warm humid climate with a well distributed rainfall of 1000mm to 2000 mm per year. Given a wide ecological diversity, cassava is subjected to highly varying temperatures, photoperiods, solar radiation and rainfall. However, the optimum temperature range for cassava is 25^{oc} – 29^{0c} (Conceicao, 1979) but can tolerate a temperature range of 16^{0c} – 36^{0c} (Cocky, 1984).

2.3 Uses of Cassava

Cassava has become an important crop in Ghana and the world over. According to Montero (2002), the world annual production of cassava is more than 158 billion tons. This amount is used for various uses including human consumption (58%), animal feed (22%), and other uses (20%).

2.3.1 Human Food

The global cassava utilization as food was put at 102 million tones in 2000, the bulk of which was consumed in Africa in the form of fresh roots and processed products (FAO, 2001). It can be harvested many times from 8 to 24 months after planting and can be left in the ground as a safeguard against unexpected food shortages which gives it advantage over cereals.

In some African countries and elsewhere, cassava may be eaten raw especially the sweet varieties by removing the skin and the rind. Fresh cassava can also be eaten by removing the charred skin after baking (Balagoplan, 2004). A flour-like meal of cassava is very popular among some communities. In Brazil, a sweet food is prepared by cooking peeled roots in sugar syrups. It is also a practice in Brazil to make a soup called ‘’*Sacncocho’’* or ‘’*cocido’’* by boiling cassava tubers with other vegetable***s (***Alagoplan *et al*., 1998). Manicurera is a boiled slightly sweet cassava drink available in the northwest Amazon region. In South America and the west Indies, ‘Farina’ is a common food prepared from fresh cassava tubers pressed in a wooden screw press, forcing the pulp through a sieve and finally, roasting it on a slow fire. It is preserved for several months and consumed as cereal in combination with several other foods. The juice pressed out of the tubers during the preparation of *Farina* is concentrated and spiced added to make the sauce known as *Cassareep* in West Indies and *Tucupay* in Brazil (Balagoplan, 2004).

Also in the Amazon regions of Brazil, yellow bitter varieties are soaked in water for two or more days, then peeled and grated. The resulting mash is mixed with fresh roots and allowed to ferment for several days before toasting.

In all locations in West Africa, cassava has become a very popular crop and is fast replacing yam and other traditional staples gaining grounds increasingly as an insurance crop against hunger. This is derived from the consumption of gari (toasted granules), chips/flour, fermented pastes and/or fresh roots. In Ghana, Nigeria, Guinea, Benin and Togo, gari is one of the most important foods (Balogoplan, 2004). It is prepared by making a pulp from fresh cassava tubers and placing it in a cloth or sacks for fermenting between 3-10 days. A good quality gari is usually creamy yellow in colour with uniformly sized grains and should swell to three times its volume when placed in water (Balagoplan, 2004). Gari accounts for 70 percent of Nigeria’s total cassava consumption ‘Fufu’, prepared by cooking peeled roots by steaming or boiling and pounding to form sticky dough which is eaten with soup prepared with any meat or fish is a common and popular food in Ghana. ‘Ampesi’ is boiled root and may be eaten alone or with some sauce in Ghana(Balagoplan, 2004).

Demand for traditional cassava foods will grow as population increases in developing countries, but consumer trends are expected to change as more and more people move to the cities. Cassava producers and processors will need to respond to the growing urban demand for foods that are more convenient or seen as more modern, such as store-bought bread and baked goods made from imported wheat flour. This is because according to George (1989), with fast strides of urbanization, life style change and to keep pace with the changes people are shifting to fast foods and instant ready to serve dishes and hence the study of cassava flour in this aspect is crucial. '*Pao de queijo'* the main cassava based fast food in Brazil (VilPoux and Ospina, 1999) is a good example of cassava in this challenge. 'Macaroni' is prepared by blending cassava flour and groundnut flour with wheat flour in a ratio of 60:12:15. It contains about 12% protein while enriched macaroni contains 12-18% protein fortified with vitamins and minerals and has been developed for feeding children and vulnerable groups(Balagoplan, 2004).

Bread consumption is constantly increasing in many developing countries, which still depending mostly on imported wheat or wheat flour while they grow various staples such as starchy tubers like cassava or cereals other than wheat. Recent experiments show the possibility of partial replacement of wheat flour in bread making by other flours. The development of high quality cassava flour could help many developing countries reduce their dependence on imported grains.

In North America for example, a traditional preparation of bread called *cazabe* is prepared by the Indians and bread such as '*pandebono'* and '*pan de yucca'* in Columbia and '*Paode queijo'* in Brazil (Baagoplan, 2004). In Jamaica, bakers of bammy bread made from cassava meal had been successful in carving out a profitable market niche. When this was tried in Ghana, remarkable results were obtained in composite bread making, pastries and biscuits. It seems quite logical that the utilization of cassava flour in bread making will increase considerably in most developing countries (FAO, 2004a)

Cassava forms a substrate for a wide variety of fermented foods and drinks in Africa. Asia and Latin America. As with Ugandan cassava beer, fermented drinks such as *beiju, banu, or Ula and Kasili,* are made after fermentation of grated cassava and are common in the tribal belts of South America (Lancaster *et al*., 1982).

2.3.2 Cassava uses as animal feed

As the standard of living improves, the demand for meat and dairy products also increases. It is, therefore, expected that livestock production will increase rapidly and significantly in many African and other developing countries. This will certainly call for corresponding increase in demand for livestock feed in the right quantities, quality and affordable prices. Though this need varies among countries where surplus cereals are available, they may provide the major energy component in animal ration. However, in less developed countries where cereals production is inadequate for direct human consumption, they must be left for human consumption while cassava must occupy the first position in times of energy source in meeting the increasing animal ration need. The use of well balanced compound feedstuffs has proved to be the most efficient way to meet the shortage of home grown natural fodder to increase efficiency in raising milk cows, beef cattle, broilers, laying hens and pigs. Many feeding experiments show that cassava provides a good quality carbohydrate source, which could be substituted for maize or barley (Balagoplan, 2004).

Global cassava utilization as feed is estimated at 34 million tonnes, most of which is concentrated in Latin America and the Caribbean and in the EC (FAO, 2004b). Even though cassava is an important staple food in a number of countries, a large share is used as feed (FAO, 1999). In Brazil, feeding livestock with fresh cassava at the farm level represents another important use of the cassava crop, accounting for 25% of total production (FAO, 2004b). When George (1989) predicted animal feed shortage of 5.8 million tons in India by the year 2000, cassava was identified as a top-ranking crop to compensate for the deficit.

2.3.3 Industrial uses of Cassava- Cassava floor and Starch

Lack of cassava market outlets was identified as the reason why it was not considered among the model crops for sustainable development (Kleih *et al*., 1994). However, a number of industrial uses have been found for cassava, which is rapidly turning it into a well-deserving industrial crop. Cassava utilization in industry is discussed here under flour and starch utilization.

Cassava flour is a potential substitute for wheat and maize based flours (Richard *et al*., 1991; Tian *et al*., 1991) A preliminary study indicated a potential substitute of local cassava flour for imported materials in the areas of plywood glue extenders and paperboard adhesives in Ghana (Graftham et al., 2000). In Ghana, 250,000t of wheat flour was imported per annum and this was mainly used by the bakeries, with about 1,200t/annum used by the plywood industry (Dziedzoave *et al.,* 2000). Much of this could be replaced with cassava flour.

In Malawi a manufacturing company used cassava and wheat flour as binders along with wood and synthetic adhesives in the production of plywood, block boards for domestic, and export markets. Using cassava flour enabled the company to reduce its wheat imports by 40 percent and save US$54,000. Other industries in Malawi are using cassava flour as filler material for adhesives as starch in the manufacture of textiles, as a partial substitute for wheat flour in biscuits and as a source of glucose. It is reported that a 15 percent substitution of cassava flour for wheat flour could save Nigeria about US$15 million a year in foreign exchange.

Starch-derived products are used in almost every industry. Cassava starches are potential substitutes for wheat and maize-based starches (Richard *et al*., 1991, Tian *et al*.,1991). On wet basis, cassava starch yield was between 24-26% but 40% was achievable (Oliver, 2000) and Asia was reported to lead the way in the production of starches derived from cassava. Cassava starch has unique properties, such as high viscosity and resistance to freezing, which makes it competitive with other industrial starches. A survey by Dziedzoave *et al*., (2000) indicated that 5000 tons of starch was used in Ghana per annum in the area of textiles (40%), plywood (27%), pharmaceuticals (20%) paper (10%) and food (3%).

In the textile industry, starch is used in the sizing operation to coat yarn, in the finishing operation, to modify appearance, change stiffness, and add weight to fabric and in the printing operation to prepare the paste of dyestuff (Balagoplan *et al*., 1998). Starch hydrosates are also a basic input in the manufacture of industrial inorganics such as alcohol, gluconic acid, and acetic acid ((Balagoplan *et al*., 1998).

Dextrin is produced by heating starch in a dry form in acid/alkaline as a catalyst (Colonna *et al*., 1987). It is used in making adhesives for use in the packaging industry for lamination in plywood, paperboard, footwear, and cable industries in the production of paper tubes, cans, and cones; as printing, publishing and library paste; and as label adhesive for envelopes, postage stamps, gummed tapes, safety matches and many other items.

Starch hydrosates which is obtained by starch hydrolysis with acid or enzyme treatment are used to impart sweetness, texture and cohesiveness to drinks such as soft drinks, fruit juice, and dairy drinks and to a variety, of foods such as soup, cake and cookie (Balagoplan *et al*., 1998)

2.4 Nutrient requirements of Cassava

Cassava (*Manihot esculenta Crantz*) is more productive than most other crops when grown on acid infertile soils. However, the crop is very responsive to better soil fertility and may require high levels of fertilization to reach its yield potential. When grown on infertile soils, cassava seldom shows clear symptoms of nitrogen, phosphorus or potassium deficiencies, but instead produces small and weak plants with a reduction in root yield. Cassava is well adapted to poor or degraded soils because of it's tolerance to low pH, high levels of exchangeable Aluminium (Al) and low concentration of phosphorus in the soil solution. When grown on light textured and low organic matter soils, cassava tends to respond mainly to Nitrogen (N) application, however due to the relatively large removal of Potassium (K) in the root harvest, continuous cassava cultivation on the same land may lead to K exhaustion and K eventually becomes the most limiting nutrient. Under normal soil conditions, cassava roots readily become infested with mycorrhizal fungi, which help the plant absorb Potassium (K) even at low external P
concentration in soil solution.

Nutrient absorption and distribution are closely related to plant growth rate which depends on soil fertility and climatic conditions as well as varietal characteristics. In poor soils, fertilizers can markedly increase plant growth and nutrient absorption while in areas with a long dry season, irrigation can do the same.

At 2-3 months after planting (MAP), the tuberous roots become the major sink of dry matter (DM). At harvest DM is highest in the roots followed by stems, fallen leaves, leaf blades and petioles. Fertilization can increase total DM production and root yield by 30% but would nearly double the absorption of P and K and increase that of N up to 61% (Paula *et al*, 1983). The roots generally accumulate more K than N followed by P, Ca, Mg and S (Putthachareon *et al*, 1998). To prevent nutrient depletion of the soil, about 60kg N, 10-20kg P_2O_5 and 50kg K_2O ha^{-1} should be applied if the expected yield level is 15 t ha^{-1} and all stems and leaves are returned to the soil. If leaves and stems are also removed, at least twice these amounts should be applied. Removal of potassium, calcium and magnesium is quite low when only roots are harvested but increases considerably (especially calcium and magnesium) if plant tops are also removed.

When cassava is grown on slopes, nutrient losses in eroded sediments and runoff can be substantial. Apart from physically removing part of the top soil with the associated organic matter, nutrients and microorganisms also reduce the depth of the top soil and sometimes even expose the subsoil. Consequently, cassava yields on eroded soils are substantially lower than on a non-eroded soil (Howeler, 1986, 1987).

Work by Putthacharoen *et al* (1998) and Wargian *et al* (1998) showed that cultivating cassava on slopes results in more erosion than for many other crops. This was mainly due to wide plant spacing and slow initial growth of cassava which left the soil exposed to agents of erosion during the first 3-4 months after planting. Simple agronomic practices such as selecting varieties with rapid initial growth, minimising tillage, closer plant spacing, vertical planting, planting-at the end rather than the beginning of the rainy season would be useful to control soil loss on such lands.

2.5 Inorganic and organic nutrition of cassava

While cassava performs better than most crops on infertile soils, the crop is highly responsive to fertilizer application. High yields can be obtained and maintained only when adequate amounts of fertilizers and /or manures are applied. Thousands of fertilizer experiments conducted by FAO (1999) indicate that cassava is responsive to fertilizer application as other crops with yield increase of 49% (West Africa) and up to 110% in (Latin America). In Ghana cassava responds mainly to K, in Brazil to P and Indonesia and China to N (Hagens and Sittibusaya, 1990).

Cassava is sensitive to over fertilization, especially with N, which will result in excessive leaf formation at the expense of root growth. Cock (1975) reported that cassava has an optimum leaf area index (LAI) of 2.5-3.1 and that high rates of fertilization may lead to excessive leaf growth. High N application would not only reduce the harvest index (HI) and root yield, but can also reduce the starch content and increase HCN content of roots. Moreover, nutrients generally interact with each other and excessive application of one nutrient may induce a deficiency in another. Howeler *et al* (1977) and Edwards and Kong (1978) have reported that high rates of lime application may actually reduce yields by reducing Zn deficiency. Spear *et al* (1978) observed that increasing the K concentration in nutrient solution decreased the absorption of Ca and Mg.

Significant responses to N have been reported more frequently in Asia than in Africa. In nearly 100 NPK trials conducted by FAO on farmers fields in Thailand, results showed a response in the order of N, K and P (Hagens and Sittibusaya, 1990). In Africa relatively few fertilizer trials have been conducted, mainly because very few cassava farmers apply fertilizer to the crop. In West Africa, the responses to N are the most frequent as reported by Okugau *et al* (1999).

Krochmal and Samuels (1970) reported a root yield reduction of 41% and top growth increase of 11% due to high N application. These high rates also stimulate production of N-containing compounds such as protein and HCN and may result in decrease in root starch content. High rates of N application may also increase the intensity of diseases such as cassava bacteria blight (Kang and Okeke, 1994). Thus N rates must not only be adjusted to a particular soil but also tailored to the needs of a particular variety.

Trials on the optimum time and partitioning of N applications have generally shown nonsignificant differences between single application at one month after planting (MAP) on various partitions (0-3MAP) using N rates up to 200kgha^{-1} (Howeler, 1985). There are usually no significant differences among N sources such as urea, NH4NO3, mono or di-amonium phosphate. Vinod and Nair (1992) reported higher yields with slow release N sources.

When inoculated with endotropic Vasicular Arbuscular Mycorrhiza (VAM), the growth of cassava in nutrient solution improved (Howeler *et al*, 1983). Masses of mycorrhizal hyphae growing in and around roots of cassava increased the plant's ability to absorb P from the surrounding medium. When planted in natural soils, the crop's fibrous roots become infected with native soil mycorrhizas. The resulting hyphae grow into the surrounding soil and help in the uptake and transport of P. Responses of cassava to P application depends on the available P level in the soil, the mycorrhizal population and variety used. Van der zang *et al* (1979) reported high yield up to 42t ha^{-1}in an oxisol with only 3µg P g^{-1} ($NaHCo_3$ extractant). CIAT (1988) also reported that some varieties produced yields of 40-50 t ha^{-1}without P application to the soil with only 4.6 µg P g^{-1} . Responses of cassava to P application have been reported in Ghana (Stephens, 1960; Takyi, 1972). On the contrary Ofori (1973) reported a negative effect of P application on cassava yields on a forest ochrosol in Ghana.

Large varietal differences have been observed in cassava's ability to grow on low P soils (CIAT, 1988). Pellet and El-Sharkavy (1993) found that varietal differences in response to applied P were not due to genetic differences in P uptake, but rather the contrasting patterns of dry matter distribution and P use efficiency. Low P tolerate cultivars had a fine root length density, moderate top growth and a high stable harvest index.

Potassium stimulates net photosynthetic ability of a leaf area and increases the translocation of photosynthate to the tuberous roots. Obigbessan (1973) reported that K application increases root yield and starch content. Root starch content increases up to 80-100kg K_2O $ha^{-1}$and then decreases at higher rates of K application. Obigbessan (1973) and Kabeerathumma et al (1990) reported that K also decreased the HCN content of roots. While Payne and Webster (1986) on the contrary found highest levels of HCN in roots produced low K soils.

The optimum time of K applications have produced contradictory results, there was no difference between single and split applications or among different times of application (CIAT, 1982) but overall, a single application at one MAP produced the highest yield.

Animal manure tends to have low nutrient content less than 10% of that contained in most inorganic fertilizers, but they also contain Ca, Mg, S and some micronutrients not found in most inorganic fertilizers (Howeler, 1980). In addition, they may improve the physical conditions of the soil. Silva (1970) reported of good responses to applications of 6-15t $ha^{-1}$of cattle manure. Howeler, (1985) reported that 4.32t ha^{-1}chicken manure increased cassava yield from 19-33t ha^{-1}. The chicken was about twice as effective as cattle manure. The total amount of nutrients applied with the chicken manure was higher than that applied in the inorganic fertilizers but beneficial effect could also be due to improved soil structure, presence of some essential elements other than NPK and the stimulation of microorganisms such as VAM.

Gomes *et al* (1983) reported that very high yields were obtained with the use of a system called 'parcagem' which is in situ application of cattle manure, where a large number of cattle are enclosed overnight on a small piece of land. It was calculated that 30 animals enclosed overnight on one hectare for sixty days will produce about 8 tons of dry manure containing 40kg N (plus N in urine). At an equal dosage of 40kg N ha^{-1}cassava yields with the parcagem (combined with additional P and K) increased 30-90% as compared to application of inorganic fertilizer. Good results were also obtained when 5t $ha^{-1}$of cattle manure was combined with 10kg P_2O_5 ha^{-1} (Diniz *et al*, 1994).

When cassava is grown continuously on the same soil without adequate fertilization or manure inputs, soil productivity may decline due to nutrient depletion and soil loss by erosion.
Sittibusaya (1993) reported that cassava yields on unfertilized soils declined from 26-30 to 10-12 t/ha after twenty years of cassava cultivation. Similar or even faster decline had been observed (Stem, 1992).

Cong- Doan and Deturk (1998) compared the effect of long-term cultivation of cassava with that of natural forest, rubber, cashew and sugarcane grown on similar soils and observed that cassava cultivation resulted in the lowest levels of soil organic carbon, total nitrogen and exchangeable potassium and magnesium and an intermediate level of phosphorus because of some phosphorus fertilizer application.

With the application of NK or NPK, yields can be maintained at a level of 20t ha^{-1} for long periods. When plant tops were reincorporated into the soil, the rate of yield decline was slower than without fertilizer application at all. Thus, when plant tops are reincorporated into the soil, yields of 10t ha^{-1}

could be maintained even in a poor soil without the use of fertilizers. With adequate fertilization, high yields of at least 20t ha^{-1} could be maintained for nineteen years of continuous cropping.

2.6 Inoculation with Mycorrhizas

Cassava can grow well in low P soils because of a highly efficient symbiosis with VAM which occurs naturally in the soil. Without VAM, cassava will require an application of at least 1-2 t $ha^{-1}$of P to obtain the same yield as plants with VAM but without P (Howeler, 1980; Howeler *et al* 1982) compared with 6 other tropical crops and forages, cassava was found to be most dependent on VAM (Howeler ,1987).

Soils however differ in both quantity and quality of native mycorrhizas and thus in the crop responses to P application (Sieverding and Howeler, 1985; Howeler *et al* 1987), *Glomus manihotis* was one of the most effective species for increasing cassava growth and yield in acid soils.

In soils with less effective native VAM population, inoculation of plants grown in sterilized soil increased yield nearly 3 fold without application of P and 164% with 100kg P ha^{-1}. Numerous experiments on VAM inoculation of cassava growing in natural soils in Columbia indicate that responses vary from location to location, depending on the efficiency of the native VAM population and the ability of the introduced species to compete with the native population. Mycorrhizas are absolutely essential for cassava growth but it seems difficult to improve on an already highly efficient, naturally occurring symbiosis.

Some common functions of beneficial soil microorganisms that affect soil fertility and crop production as reported by Higa and Parr (1994) include the following: (i) assist in the recycling and increased availability of plant nutrients, (ii) enhance the decomposition of soil organic matter, (iii) fixation of atmospheric nitrogen, (iv) solubilization of insoluble nutrient sources, (v) degradation of toxicants including pesticides, (vi) production of polysaccharides to improve soil aggregation and (vii) production of antibiotics and other bioactive compounds.

Higa and Parr (1994) added that microorganisms are unique in their biosynthetic capabilities under a specific set of environmental and cultural conditions. This makes them suitable candidates not only for agricultural use but useful in other fields such as medical technology, food processing, genetic engineering, environmental protection and waste management as well.

Higa (1991) isolated and mixed pure cultures of microorganisms that had beneficial effect on soil and plants. Those mixed cultures that were physiologically compatible produced a synergistic effect on the soils and crops to which they were applied. He then named these cultures as effective microorganisms.

Effective microorganisms are prepared from cultures of naturally occurring species of microorganisms from the genus *Streptomyces*, photosynthetic nitrogen fixers, *Lactobacillus*, yeast and molds (Husain, 1994)

The mechanism for increase in crop yields with the use of effective microorganisms has not yet been quantified though the beneficial nature of the organisms had been reported; Sanakkara and Higa ,1992).

Major constraint in the control of microflora of agricultural soils include the large numbers and types of microorganisms present in the soil at any one time and fluctuations in their populations as a result of man's activities. Diversity in the types and population of microorganisms in any soil depends on the conditions prevailing in the soil's environment and the factors that affect the growth and activities of the microorganisms such as; temperature, light, organic matter, pH and water. Many organisms respond to these factors whereas a few may show little response.

The use of mixed cultures of microorganisms as a soil inoculant simulates what happens in a natural ecosystem where great diversity and number of inhabitants will lead to increased order of interaction and a more stable ecosystem. So the principle of mixed cultures of microorganisms is simply to shift the microbiological equilibrium in favour of increased plant growth, production and protection (Higa, 1991).

Higa and Wididana (1991) reported that most fertile soils have a large population of highly diverse microorganism as well as high content of organic matter. Such soils will usually have a wide ratio of beneficial to harmful microorganisms.

High temperatures increase the incidence of pests and diseases which have the effect of reducing crop yield. Pesticides can be used to control these pathogens but these may have a residual effect on consumable crops. Other practices such as shading or mulching can be used to reduce temperature and thereby minimising the populations and activities of these organisms. Another approach is to inoculate the soil with beneficial, antagonistic, anti-biotic-producing microorganisms such as actinomycetes and some fungi (Higa and Wididana, 1991a; 1991b).

Higa (1995) stated that the microflora of disease-suppressive soils is usually dominated by antagonistic microorganisms that produce copious amounts of antibiotics. These include fungi of the genera *Penicillium*, *Trichoderma*, *Aspegillus and Actinomycetes* of the genus *Streptomyces.* The antibiotics they produce can have biostatic and biocidal effects in soil-borne plant pathogens including *Fusarium* which would have an incidence in soils of less than five percent. Crops planted in these soils are rarely affected by diseases and pests. Where even fresh organic matter with high nitrogen content is applied, the production of putrescent substances is very low and the soil has a pleasant earthly odour after the organic matter is decomposed. Such soils usually have good physical properties like formation of well-aerated stable water aggregates. Crop yields in the disease-suppressive soils are often slightly lower than those in synthetic soils. Better yields are obtained whenever a soil has a predominance of both disease-suppressive and synthetic microorganisms.

Higa (1995) observed that there could be a variation in the desired effect from the application of cultural effective microorganisms to the soil. It was discovered that in some soils, a single application was sufficient to produce the desired effects whereas in others, repeated applications appeared not to produce the desired results. The reason for this is that in some soils it takes a longer time for the introduced microorganisms to adapt to the new environment and play their role in bringing about the desired effect. It is therefore, important to make a careful selection of a mixed culture that is compatible, effective and properly cultured and provided acceptable organic substances. It was also observed that repeated applications made at regular intervals during the first cropping season have the probability of achieving the desired results.

The initial populations of beneficial microorganisms should be at a certain critical threshold level if these organisms are to be effective after inoculation. This will ensure that the amount of bioactive substances produced by them will be sufficient to achieve desired results otherwise little or no effect will be observed no matter how useful they may be. At the moment there is no inorganic tests that can predict the probability of a particular soil-inoculated microorganism to achieve a desired effect. The most reliable approach is to inoculate the soil as part of a mixed culture, and then at a very high inoculum density to maximize the probability of it's adaptation to environmental and ecological conditions(Higa and Wididana, 1991)

Again, Higa (1991) observed that application of suitable concentrations of effective microorganisms provides better conditions for crop growth in organic systems. The benefits become clear over time with changes in the rhizosphere. Application of effective microorganisms does not provide significant benefits except in the presence of suitable organic matter as in the natural farming systems. Organic matter with a low C:N ratio is suitable because it provides readily available carbon for growth and activity of microorganisms which in turn enhances the release of large quantities of plant nutrients with minimal loss. It was also observed that effective microorganisms have the capacity to improve the physical properties of the rhizosphere.

Higa (1991) observed that the effects of effective microorganisms were much better in the wet seasons. This means that adequate soil moisture is required for the multiplication and activities of the effective microorganisms applied to the soil.

There are no reliable tests for monitoring the establishment of mixed cultures of beneficial and effective microorganisms after application to the soil(Higa, 1991). The desired effects appear only after they are established and become dominant and remain stable and active in the soil. The inoculum densities of the mixed cultures and the frequency of application serve only as guidelines to enhance the probability of early establishment. Repeated applications, especially during the first cropping season, can markedly facilitate early establishment of the introduced microorganisms.

2.7 Role of Terramend 21 (TM21) in plant growth and yield

Terramend 21 (TM21) is a biostimulant and soil rejuvenator that promotes microbial activity in the soil. It feeds and increases the population of beneficial microorganisms resulting in better soil environment for plant growth and development (BEST, 2004). It helps to unlock the nutrients in the soil and this enables plant roots to take up essential nutrients for good plant performance. It also helps to improve soil structure and texture.

The greatest strength of TM21 is that it applies the principles of a healthy ecosystem to a farm setting. These principles are that every organism is linked to the organisms around it by a huge web of relationship. If one link becomes stressed, the rest will also feel the effect of that stress. TM21 restores the health of soil microbiota such as bacteria, actinomycetes and fungi. They are the ones that actually do the work of soil improvement. By boosting their numbers, TM21 increases the strength of the whole system. Inorganic fertilizers can not do this because they artificially change a small portion of the soil's nutrient system resulting in an unbalanced ecosystem. Anything growing in it becomes stressed including crops. The crops are forced to compensate for this stress leaving them with less energy for reproduction and forming their proteins properly. TM 21 is safe, effective and best of all good for the environment. It restores the vitality of nutrient depleted soils by stimulating the microorganisms that breakdown the parent rock into soil. The resulted nutrients are stored in humus form (BEST, 2004).

Caldwell (2003) reported that TM21 increased root growth and had an inhibitory effect upon pathogenic organisms under cool water-logged conditions. He also added that as the amount of TM21 increases, the rate of destruction of beneficial bacteria decreases.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at the Plantation Crops Section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, Kumasi from September 2005 – September 2006. It falls within Latitude 6, 43 North and 1, 36 west.

3. 2 Climate and vegetation

The rainfall regime is bimodal averaging about 1302mm per annum. The major season is from March to July and the minor from September to November. The temperature is high throughout the year with the minimum mean of about 24.6 °C in August and mean maximum of 28.2 °C. The vegetation is the semi-deciduous forest type. The soil is of the Kumasi series type, Utisol developed over biotic granite. It is a moderately drained sandy clay loam. Previous crops cultivated at the experimental site over the last 10 years include maize, cowpea and cassava.

3.3 Experimental design and treatments.

The experimental design was a split-plot with four replications. The two cassava varieties were assigned to the main plots, while the five soil amendments were assigned to the sub-plots. Each plot measured 5.0 m x 8.0m with five rows of length 8m each.

The treatments were: - Main plots (two cassava varieties –IFAD and Nkabom) and sub-plots (five soil amendments): (i) To – control, (ii)TI – TM21 at a rate of 250ml/ ha, (iii) T2 – NPK at a rate of 60-40-40kg /ha, (iv) T3 – TM21 at a rate of 250ml/ha and fertilizer at a rate of 30-2020 kg/ha N.P.K and (v) T4 – Poultry manure at a rate of 4t/ha.

The two cassava varieties (Nkabom and IFAD) were acquired from the cassava multiplication unit of the Ministry of Food and Agriculture, Mampong. They have maturity period of 120 days.

Both varieties have a potential yield of 30t/ha.

3.4 Cultural/Management Practices

The land was ploughed and left for two weeks and harrowed to control weeds. The cassava cuttings of 15-20cm long were planted at a spacing of 1m x 1m.Three manual weedings were done during the growing period.

N.P.K was applied at the rate of 60-40-40kg/ha and poultry manure at the rate of 4t/ha at four weeks after sprouting. All fertilizers were placed 5cm away around the cassava plants and covered with soil using a hoe.

Terramend 21 (TM 21) application: This was applied three times during the growing period of the crop at a rate of 250ml/ha before planting, at five weeks after planting (5 WAP) and twelve weeks after planting (12 WAP) using a knapsack sprayer.

3.5 Soil Chemical Analysis

Soil samples were taken at a depth of 0-15cm and 15-30cm at the beginning of the experiment and at harvest. These samples were at the laboratory to determine their physical and inorganic properties. The samples were dried and sieved using a 2mm mesh sieve. The following properties were determined.

3.5.1 Organic Carbon and organic matter

The walkley-Black wet combustion procedure (Nelson and Sommers, 1982) was used to determine Organic carbon. Percent organic carbon was multiplied by 1.724 (The Van Bemmelen factor) to get percent organic matter.

3.5.2. Soil pH.

This was measured in 1:2:5 soils to water suspension by the use of a glass Electrocalomel electrode (Mclean, 1982) pH metre.

3.5.3 Total Nitrogen

The Macro Kjeldahl method described by Bremner and Mulvaney (1982) was used. A 10g soil sample (< 2mm in size) was digested with a mixture of 100g potassium sulphate, 10g copper sulphate and 1g elenium with 30mls of concentrated suferic acid. This was followed by distillation with 10ml boric acid (4%) and 4 drops of indicator and 15mls of 40% NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14g of nitrogen is contained in one equivalent weight of NH3, the percentage of nitrogen in the soil was calculated as follows:

$$\% \text{ Nitrogen } \frac{14}{1000 \times 1} \times (A - B) \times N \times 100$$

Where,

A = Volume of standard acid used in the titration.

B = Normality of the standard acid.

3.5.4 Potassium

The flame photometre method was used to determine the amount of potassium with ammonium acetate as the extractant.

3.5.5 Available phosphorous

The Bray-1 P method was used for the determination of phosphorus with dilute acid fluoride as the extractant.

3.5.6 Exchangeable Bases (Ca, Mg, K, Na)

The exchangeable base cations were extracted using ammonium acetate (NH4OAc) at pH of 7.0. Calcium and Magnesium were determined using the EDTA titration method (Moss, 1961) while potassium and sodium were determined by the flame photometer.

3.5.7 Exchangeable Acidity (AL and H)

Exchangeable acidity (AL and H) was extracted with 1m KC1 solution. The extract was then titrated with 0.05N NaOH and 0.05 HCL and 10ml NaF solution added. This AL, H was then determined by extracting (AL + H) (Mclean, 1965)

3.5.8 Starch Determination

The Reiman Balance was used to determine the starch content. It works based on the specific gravity. Two kilograms of tubers were taken and immersed in water and the weight taking using the balance. The difference in weight was equal to the starch content.

3.6 Sensory evaluation

Cassava tubers were taken from each treatment and boiled for 45minutes. These were ranked by experienced chop bar operators for the mealiness of the tubers.

3.7 Other Data Collected

The response variables measured were:

3.7.1 Microbial Colony of Soil before planting and at harvest

Soil samples were taken from the whole field and mixed together thoroughly before planting the cassava. Sub-samples were taken to the laboratory and cultured for microbial growth. The microbial colonies were recorded after four days. For each treatment, three soil samples were taken from each plot and mixed together thoroughly at harvest. Sub-samples were taken to the laboratory where it was cultured for microbial growth. The microbial colonies were recorded after four days.

3.7.2 Plant Height

Plant height was measured at three months after planting and then every month for seven months. Five plants from the central row of each plot were randomly selected and the measurement taken from the soil level to the terminal end of the plant using a graduated pole.

3.7.3 Mean Fresh Shoot Weight

The fresh shoots of a number of stands were cut and weighed. The mean weight was determined as:

$$\text{Mean Fresh shoot weight} = \frac{\text{Total shoot weight}}{\text{Number of Stands}}$$

3.7.4 Number of Tubers/Plant

At harvest ten plants were randomly selected and harvested. The number of tubers / plant was determined from the relation below

$$\text{No. of tubers/plant} = \frac{\text{Number of Tubers harvested}}{\text{Number of plants}}$$

3.7.5 Tuber Mean weight

Ten tubers were randomly selected and weighed. The mean weight was calculated as

$$\text{Tuber mean weight} = \frac{\text{Weight of Tubers}}{\text{Number of tubers}}$$

3.7.6 Harvest Index

Five stands were selected from each plot at harvest. Weight of above ground biomass and that of the tubers were recorded. The Harvest Index (HI) was calculated as

$$\text{H.I.} = \frac{\text{Weight of Tubers}}{\text{Weight of total biomass}}$$

3.7.7 Tuber Dry Matter (%)

A random sample of tubers were taken and chopped into smaller pieces. These pieces were mixed and 200 g taken and oven dried at 80^{0c} for 72 hours. The weight after constant value was recorded and dry matter content calculated as:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Wet weight}} \times 100$$

3.7.8 Tuber Yield (t / ha)

The middle three rows which covered an area of $24m^2$ were harvested for tuber yield assessment.

The yield of the fresh tubers in t/ha was calculated as:

$$\text{Tuber yield (t/ha)} = \frac{10{,}000 \times \text{weight of tubers from harvested stands}}{\text{Number of stands harvested}}$$

3.8 Data Analysis

Data was analysed using the Costat Statistical package. Analysis of Variance (ANOVA) was used to determine the treatment effect on response variables. Differences between treatment means were determined using the Least Significance Difference (LSD) at 5% level of probability.

CHAPTER FOUR

RESULTS

4.1 Rainfall/Climate

Table 4.1: Rainfall data for September 2005 – September 2006

Table 4.1 presents the rainfall data for the period of the study. Except for December 2005, rainfall was recorded throughout the growing period. The distribution was normal with the lowest and the highest rainfall of 68.5mm and 143.9mm recorded in 2006 respectively. The total amount of rainfall was 1254.7mm during the growth period.

Table 4.1: Rainfall data for September 2005 – September 2006

Year	Month rainfall (mm)												
-	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total
2005									169.2	224.6	54.5	0	448.3
2006	109.9	113.9	91.4	93.2	143.9	113	68.5	75.8	96.8				906.4

Table 4.2 shows microbial colony of the soil before planting and at harvest. Before planting, microorganisms present in the soil were *A. flavus*, *Rhizopus*, *A. niger*, *Fusarium sp* and Unidentified colonies. *A. niger* was highest and the Unidentified the lowest. At harvest, the results showed micro-organisms in all the treatments. Fertilizer treatment gave the highest number of colonies (35) and Fertilizer with TM 21 gave the lowest value (13). Terramend 21 treatment did not contain *Aspergillus niger* and *Fusarium* sp but contained the highest number of unidentified microorganism colonies

Table 4.2: Microbial Colony of the soil before planting and at harvest

Treatment	Micro-organisms (no. identified)					
	A.flavus	*Rhizopus*	*A.niger*	*Fusarium sp*	Unidentified	Total
			Before planting			
Bulk/Composite Sample	3	5	6	2	1	17
			At harvest			
Control	5	3	7	3	2	20
Terramend 21	13	6	-	-	8	27
NPK (60-40-40kg/h	12	2	12	6	3	35
TM21+NPK(30-20-20kg/ha)	4	1	3	4	1	13
Poultry manure	7	1	10	1	3	22

4.2 Soil Chemical Properties at Planting and Harvest

The soil inorganic properties at planting and harvesting are shown in Tables 4.3 and 4.4 respectively. The pH value at planting ranged from 5.0- 6.5 whilst that at harvest ranged from 5.2-5.9 indicating an acidic condition. The range for organic matter at planting was 1.6-2.8 but was reduced at harvest to 1.0-1.8 showing a reduced organic matter content.

The range for Total nitrogen, P and K at planting was 0.08-0.13, 21.00-61.00 and 2.05-2.08 respectively. These initial quantities were inadequate to meet the nutrient requirement for the growth of cassava.

The range for Total nitrogen, P and K at harvest were 0.06-0.11, 11.00-44.00 and 0.05-0.20 respectively.

Table 4.3: Chemical Properties of the Soil at time of planting

TREATMENT	Horizon					EXCHANGEABLE CATIONS						
		pH	OC	OM	TN	Ca	Mg	K	Na	Al	H	Av. P
			----- %	--------------------			Cmol/Kg/Me/100g------					(mg/Kg)
						(0 – 15cm)						
Control		5.1	1.44	2.48	0.13	3.00	3.2	2.08	2.08	0.8	4.4	42.0
Terramend 21		5.2	1.57	2.68	0.13	3.40	3.2	2.08	2.23	.6	2.9	49.0
Fertilizer		5.2	1.27	2.20	0.10	3.60	1.8	2.07	2.24	0.8	6.0	49.0
TM 21 + Fert.		5.3	1.61	2.78	0.10	3.00	2.6	2.08	2.21	0.8	6.4	52.0
Poultry Manure		6.5	1.32	2.26	0.10	5.00	1.2	2.06	2.24	0.6	5.2	24.0

Table 4.4: Chemical properties of the soil at harvest.

TREATMENT Horizon	pH	OC	OM	TN	Ca	Mg	K	Na	Al	H	Av. P (mg/Kg)
		---------%----------------			Cmol/Kg/Me/100g -----------						
(15-30cm)											
Control	5.0	1.42	2.44	0.08	2.40	2.6	2.05	2.05	.4	1.9	34.0
Terramend 21	5.2	1.09	1.89	0.08	2.80	2.6	2.06	2.18	0.4	4.0	34.0
Fertilizer	5.2	1.06	1.82	0.08	3.00	2.4	2.05	2.21	0.8	4.2	30.5
TM 21 + Fert.	5.3	0.94	1.62	0.10	2.80	2.6	2.06	2.21	0.8	4.0	61.0
Poultry Manure	5.2	1.08	1.86	0.08	2.40	0.6	2.05	2.24	0.4	3.6	21.0

4.3 Soil Physical Properties.

The results in Table 4.5 show 46-48% sand, 8-10% silt and 42-44 % clay for the topsoil which from the textural class, is classified as a sandy clay soil. The subsoil followed a similar trend and was of the same textural class.

Table 4.5a: Physical Properties of the Soil at time of planting

TREATMENT	SAND (%	SILT (%)	CLAY (%)
		(0 – 15cm)	
Control	48	8	44
Terramend 21	46	10	44
Fertilizer	48	10	42
TM 21 + Fert.	50	8	42
Poultry Manure	46	10	44

Table 4.5b: Physical Properties of the Soil at time of planting

TREATMENT	SAND (%)	SILT (%)	CLAY (%)
		(15 – 30cm)	

Control	48	10	42
Terramend 21	44	12	44
Fertilizer	46	14	40
TM 21 + Fert.	46	14	40
Chicken Manure	44	12	44

4.4.1: Effect of soil amendment on plant height

Generally, plant height increased for all the treatments from three to ten months after planting (MAP). However, application of Poultry manure and the control treatment appeared to have produced the highest and lowest plant height, respectively at most of the sampling periods as shown in Fig. 1.

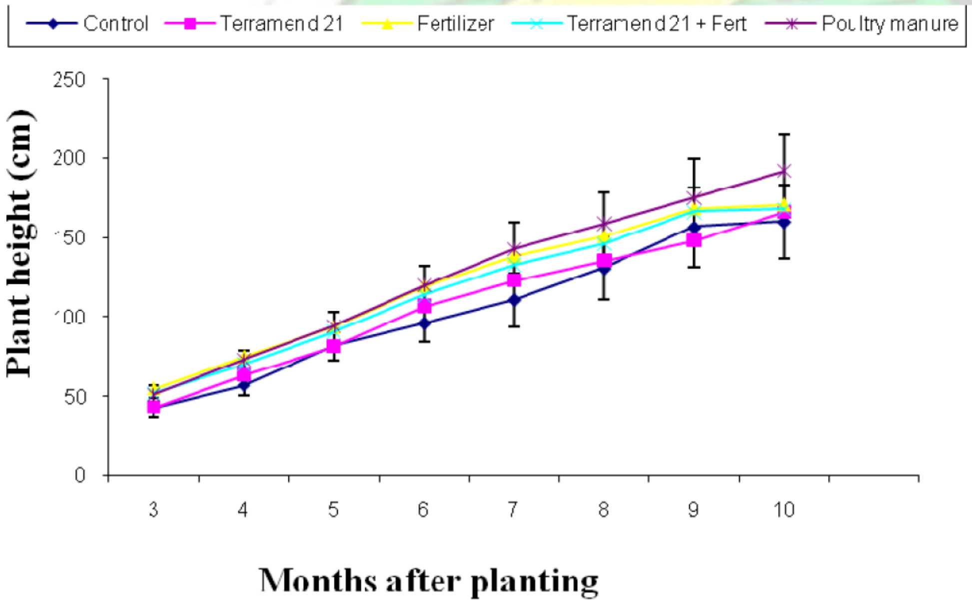

Figure 4.1a Effect of Soil Amendments on Plant Height

4.4.2 Effect of Variety on plant height

Results in Figure 2 present plant height of the varieties. Plant height increased steadily from three months after planting to the 10th month after planting (MAP) for the two varieties. IFAD recorded greater height than NKABOM at all the sampling period except at the 3rd month after planting (MAP).

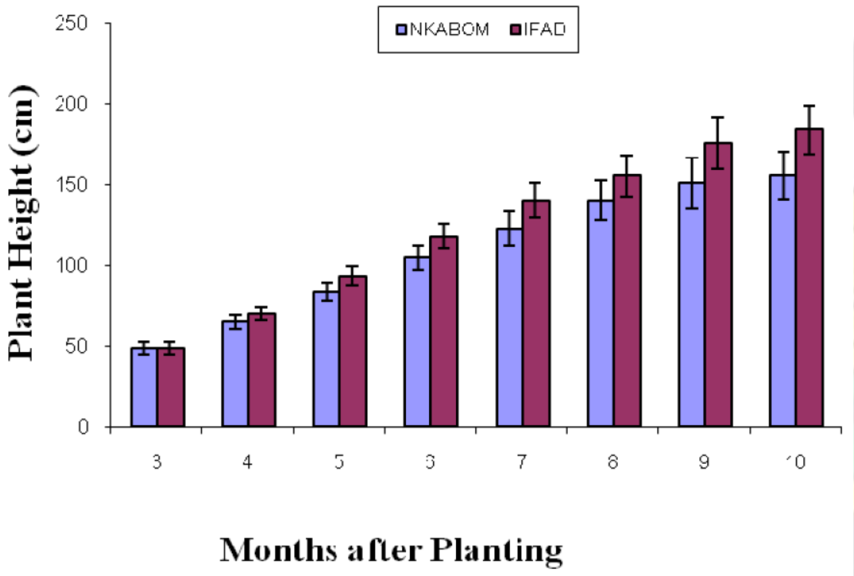

Figure 4.1b: Effect on variety on plant height

4.5: Effect of variety and soil amendments on mean fresh shoot weight

Results for the fresh shoot weight are shown in Table 4.6 The range of values for NKABOM was from 1.1kg to 1.7kg while that of IFAD was between 1.5kg and 2.1kg. The highest and the lowest values of the varieties were produced by the Control and the application of the Fertilizer, and the

Poultry manure for NKABOM but that of IFAD was by the Fertilizer + TM21 and Poultry manure. While differences in shoot weight for both varieties as affected by the application of the soil amendments were significant ($P<0.05$) that for the varieties were not statistically different ($P>0.05$). The interactions between the varieties and the soil amendments applied were significant ($P<0.05$).

Table 4.6 Effect of variety and soil amendments on mean fresh shoot weight

Soil Amendments	Variety Shoot weight (kg)		Mean
	NKABOM	IFAD	
Control	1.1	1.6	1.3
Terramend 21	1.4	1.8	1.6
Fertilizer	1.7	1.6	1.7
Fertilizer + TM 21	1.5	1.5	1.5
Poultry Manure	1.7	2.1	1.9
Mean	1.5	1.7	

LSD (5%) Variety (v) = 0.31 Treatment (T) = 0.50 VxT = 0.70 C V(%)=30.5

4.6: Effect of soil amendment and variety on number of tubers/plant.

Results of the number of tubers/plant are shown in Table 4.6. No significant differences (P>0.05) existed between the varieties. The range of values recorded by NKABOM and IFAD were 4.6 – 7.7 and 5.9 – 7.8 respectively. The highest and the lowest values for NKABOM were obtained by the application of Fertilizer and Terramend 21. That of IFAD was produced by the application of Poultry manure (7.8) and the Terramend 21 (5.9) respectively. The interaction between soil amendment and variety was significant (P<0.05). For example, while IFAD obtained the highest number of tubers/plant for the control, Terramend 21 and the Poultry manure, the highest number of tubers/plant for the application of the Fertilizer and TM 21 + Fertilizer was recorded by NKABOM.

Table 4.7. Effect of Soil Amendments and Variety on number of Tubers/plant

TREATMENT	VARIETY		MEAN
	NKABOM	IFAD	
Control	6.3	6.8	6.5
Terramend 21	4.6	5.9	5.3
Fertilizer	7.7	7.1	7.4
TM 21 + Fertilizer	6.7	6.5	6.6
Poultry Manure	7.5	7.8	7.5
MEAN	6.2	6.8	

LSD (5%) Variety (V)=0.69; Treatment (T)=1.09; VXT=1.54

CV(%)=16.0

4.7: Effect of soil amendment and variety on mean tuber weight.

Results of the tuber weight as shown in Table 4.8 indicate no significant differences ($P<0.05$) between the varieties. The ranges of values produced by the varieties were 0.4 – 0.8kg in Nkabom and 0.5 – 0.7kg in IFAD respectively. Application of Terramend 21 and the Control gave the highest and the lowest values for the two varieties. Significant differences ($P<0.05$) was observed between the treatments. Significant treatment interactions ($P<0.05$) were observed between the soil amendment treatments and the varieties.

Table 4.8: Effect of Soil Amendments on mean Tuber Weight

SOIL AMENDMENTS	VARIETY (kg)		MEAN
	NKABOM	IFAD	
Control	0.4	0.5	0.4
Terramend 21	0.8	0.7	0.8
Fertilizer	0.5	0.6	0.5
TM 21 + Fertilizer	0.7	0.6	0.6
Chicken Manure	0.5	0.6	0.6
MEAN	0.6	0.6	

LSD (5%) Variety (V)=0.12; Treatment (T)=0.19; VxT =0.27

CV(%)=29.9

4.8: Effect of Soil Amendments and Variety on tuber Yield

Result for tuber yield is represented in Table 4.9. Variation in tuber yield for the varieties as affected by the application of the soil amendments was statistically different (P<0.05). The tuber yield for NKABOM ranged from 25.2t/ha to 46.9t/ha. That of IFAD was between 27.0 t/ha and 46.8t/ha. The highest and the lowest tuber yield for NKABOM were given by the application of Fertilizer + TM 21 and the Control respectively. The Control and the application of Poultry manure produced the lowest and the highest tuber yield for IFAD. There was significant (P<0.05) interactions between the varieties and the soil amendment.

Table 4.9: Effect of Soil Amendments and Variety on tuber Yield

Soil Amendments	Variety Yield (t/ha)		Mean
	NKABOM	IFAD	
Control	25.2	27.0	26.1
Terramend 21	36.8	41.3	39.1
Fertilizer	38.5	42.6	40.6
Fertilizer + TM 21	46.9	39.0	39.0
Poultry Manure	37.5	46.8	42.2
Mean	37.0	39.3	

LSD (5%) Variety (V) = 3.58 Treatment (T) = 5.66 VxT = 8.00

4.9: Effect of soil amendment and variety on harvest index.

The varieties showed no significant differences (P<0.05) in harvest index (Nkabom 0.7) and (IFAD 0.7) as indicated in Table 4.10. Whilst values obtained by Nkabom did not differ significantly (P>0.05), that of IFAD differed significantly (P<0.05) in a narrow range of 0.6 – 0.7.This shows significant interaction between the soil amendment and the varieties. Application of Poultry manure and TM 21 + Fertilizer gave the lowest value for IFAD. The highest value for IFAD was produced by the application of the other treatments.

Table 4.10: Effect of Soil Amendments on Harvest Index

SOIL AMENDMENTS	VARIETY NKABOM	IFAD	MEAN
Control	0.7	0.7	0.7
Terramend 21	0.7	0.7	0.7
Fertilizer	0.7	0.7	0.7
TM 21 + Fertilizer	0.7	0.6	0.7
Poultry Manure	0.7	0.6	0.7
MEAN	0.7	0.7	

LSD (5%) Variety (V)=0.04; Treatment (T)=0.07; VXT=0.09 CV(%)=9.3

4.10: Effect of soil amendment and variety on dry matter content.

Dry matter content ranged from 39.7% to 45.6% as presented in Table 4.11. The average dry matter content of Nkabom (42.4%) and IFAD (43.4%)] was not statistically different (P>0.05). The ranges obtained by the varieties were Nkabom (40.3 – 45.5%) and IFAD (39.7 – 45.6%) respectively. These values were given by the Control and the application of Poultry manure for Nkabom, and the Control and the Terramend 21 for IFAD. Results showed significant interactions between the varieties and the soil amendments. Differences in dry matter as obtained by the application of the soil amendments was significant (P<0.09) for both varieties.

Table 4.11: Effect of Soil Amendments on Tuber Dry Matter

SOIL AMENDMENTS	VARIETY (%)		MEAN
	NKABOM	IFAD	
Control	40.3	39.7	40.0
Terramend 21	42.9	45.6	44.2
Fertilizer	42.7	42.8	42.8
TM 21 + Fertilizer	40.4	44.7	42.5
Poultry Manure	45.5	44.2	44.8
MEAN	42.4	43.4	

LSD (5%) Variety (V)=2.65; Treatment (T)=4.23; VXT=5.96

CV(%)=9.6

4.11: Cooking Quality.

The cooking quality of the tubers ranged from good to very good (2- 3) with the application of soil amendments. Combined application of TM21 + Fertilizer recorded the lowest value of good (2.0)for Nkabom whilst IFAD gave similar value for the control treatment (Table 4.12). The varieties did not differ from each other in tuber quality. Similarly, soil amendments soil amendment did not affect the tuber quality significantly.

Table 4.12: Effect of Soil Amendments on Cooking Quality (Score 1 - 4) +

SOIL AMENDMENTS	VARIETY		MEAN
	NKABOM	IFAD	
Control	3.0	2.0	2.5
Terramend 21	3.0	3.0	3.0
Fertilizer	3.0	3.0	3.0
TM 21 + Fertilizer	2.0	3.0	2.5
Poutry Manure	3.0	3.0	3.0
MEAN	2.8	2.8	

+ *1=poor; 2= good; 3= very good; 4=excellent.*

4.12: Starch Content.

The mean starch content of the varieties was 25.1% for Nkabom and 25.7% forIFAD as shown in Table 4.13. The difference between the varieties was not significant. The starch content recorded for soil amendments for Nkabom ranged from 24.2% to 26.9% and were respectively produced by the application of TM 21 + Fertilizer (24.2%) and Poultry manure (26.9%). However, starch content for IFAD showed significant difference ($P<0.05$) with the Control and Terramend 21 recording 23.4% and 27.8% respectively. The variation in response of the varieties to the soil amendments showed significant ($P<0.05$) interaction.

Table 4.13: Effect of Soil Amendments on Starch Content

SOIL AMENDMENTS	VARIETY (%)		MEAN
	NKABOM	IFAD	
Control	24.3	23.4	23.9
Terramend 21	25.0	27.8	26.4
Fertilizer	25.3	25.0	25.1
TM 21 + Fertilizer	24.2	25.9	25.0
Poultry Manure	26.9	26.1	26.5
MEAN	25.1	25.7	

LSD (5%) Variety (V)=1.84; Treatment (T)=2.91; VXT=4.12 CV(%)=11.2

4.13 Correlation of Tuber Yield and Yield Components

The relationship between number of tubers/plant, tuber mean weight, dry matter content, starch content and tuber yield was compared. The results in Table 4.14 showed a positive correlation between tuber dry matter and starch content, tuber mean weight and tuber yield, tuber dry matter content and tuber yield. A negative correlation existed between number of tubers/plant and tuber mean weight.

Table 4.14 Pearson Correlation Matrix of Yield andYield Components

	1	2	3	4	5
1	1.000				
2	-0.592	1.000			
3	0.079	0.265	1.000		
4	0.064	0.229	0.949	1.000	
5	0.244	0.594	0.469	0.437	1.000

Intercept = 62.4 $r^2 = 0.92$ **significant at 0.01

1 - Number of tubers/plant

2 - Tuber Mean weight (kg)

3 - Tuber yield

4 - Dry matter content (%)

5 - Starch content (%)

CHAPTER FIVE

DISCUSSION

5.1 Soil biological, chemical and physical properties

The results showed an increase in the number of microorganisms in the soil at harvest. This increase could be due to an improvement in the soil condition as a result of the addition of organic and inorganic fertilizers. The addition of TM21 could increase the number of microorganisms because it is known to improve the soil structure and unlock nutrients in the soil making them available. Best (2004) made a similar observation and reported that TM21 unlocks nutrients in the soil and restores the health of microbes such as bacteria, actinomycetes and fungi.

The increase in the number of microorganisms could also be attributed to the physiological compatibility of these organisms. This observation agrees with the report by Higa (1991) that micro organisms which can coexist in mixed cultures are physiologically compatible. There were complete absence of *A. Niger and Fusarium sp* at harvest. This could be due to the release of some inorganics by some of the microorganisms that affect the survival of others. A similar report was made by Higa and Parr (1994) that some soil microorganisms produce copious amounts of antibiotics that have biostatic and biocidal effects on other soil borne organisms.

There was a decrease in the plant nutrients in the soil. This could be attributed to the continuous use of the land for crop production for seven years without any sustainable soil management practices. Crop removal, leaching and volatilization, and reduction of nitrogen particularly $NH4^{+}$ through nitrification may lead to nutrient depletion. The slight increase of plant nutrients in plots treated with TM21 and poultry manure could be attributed to improvement of the soil structure and reduced nutrient losses through leaching. A similar observation was made by Best (2004) that TM21 improves the soil structure and nitrogen fixation but reduces leaching of nutrients from the soil.

5.2 Cassava vegetative growth (Plant height and fresh shoot weight)

Reduction in plant height could be attributed to inadequate rainfall. The total rainfall during the period was 1254. 7mm which lower than the rainfall requirement for the optional growth of cassava which is around 1000-2000mm. Plants treated with poultry manure recorded the highest plant height than the control treatment. These results, apart from providing nutrients to the plants, could also improve the soil structure by improving soil aggregation and thereby reducing the loss of water and nutrients from the reach of plants. Howeler (1980) made a similar observation and reported that poultry manure apart from providing NPK, also contained Ca, Mg, and other micronutrients that are not included in inorganic fertilizers. He also observed that poultry manure improved soil structure and stimulated activities of soil microorganisms. These reasons could also be attributed to the highest values for fresh shoot weight recorded for the varieties.

5.3 Tuber yield and Yield components

Result in Table 4.7 indicated that the higher and lower number of tubers/plant for Nkabom were produced by fertilizer application and TM21 respectively, while the higher and lower for IFAD were produced by poultry manure and TM21 respectively. The mean tuber weight for the varieties was similarly lower, for the applied treatments. TM21 produced the highest and the control the lowest value. TM21 produced the lowest number of tuber/plant but gave highest mean tuber weight. This may be attributed to source-sink relationship and the partitioning of the dry matter. If dry matter from the source should be distributed to many sinks, then the size of the sink may reduce as compensatory effect for the sinks.

Variation in tuber yield as affected by the applied treatments was significant (p<.05). The highest yield in Nkabom was produced by fertilizer combined with TM21 while IFAD recorded highest yield under poultry manure. TM21 alone could not produce highest yield because it depended on the availability of suitable organic matter with a low C:N ratio for increased efficiency. Results in Table 4.3 indicated that the soil had low organic matter and this made TM21 alone inefficient. This agrees with the observation made by Higa (1991) who reported that effective microorganisms can only be efficient in improving soil conditions when provided with a suitable organic substrate. The results produced by a combination of TM21 and fertilizer could be attributed to the ability of TM21 to reduce leaching of nutrients by improving the soil structure and thereby making nutrients available to crops. High yields produced by poultry manure may be attributed to its ability to improve soil structure through aggregation of soil particles to reduce loss of water and nutrients from the root zone of plants and the provision of NPK and other nutrients that are not contained in mineral fertilizers. The mean yield of 42.2t/ha produced by application of poultry manure was higher than the results reported by However (1985) of 31.1 t/ha. Variation in the yields could be attributed to the efficiency of partitioning of dry matter to the sinks. The two varieties had similar harvest index of 0.7. This is close to the harvest index reported by Baafi and Safo-Kantanka (2008) of 0.64 for the same varieties. Mean yield of 37.0 and 39.3 t/ha for Nkaboan and IFAD respectively were slightly higher than those reported by Baafi and Safo-Kantanka (2008) for the two varieties of 31.7 and 36.7 for Nkabom and IFAD respectively. Variation in the results could be attributed to application of soil amendments, distribution and quantity of rainfall. For instance, TM21 enhanced the value of organic matter content by accelerating its decomposition and release of nutrients for crop use as reported by Higa and Wididana (1991). It also increases yield by12.9% to 25.3% as reported by Best (2004).

Paula *et al* (1983) reported that fertilization can increase root yield of cassava by 30%, while FAO (1999) reported increase crop yields of up to 49%. The total rainfall of 1254.7mm during the period of growth could have contributed to the yield values obtained.

The results in Table 4.14 showed a positive correlation between tuber mean weight and tuber yield. This is because yield depends on the number of tubers and tuber mean weight. However, the correlation between number of tubers/plant and tubers mean weight was negative. This may be attributed to the source-sink relationship and its compensatory effect. For example if there are many tubers to accept dry matter, from a limited photosynthetic factory, the weight of the tubers will be less than if the same quantity was to be partitioned to fewer tubers.

There was also a strong positive correlation r = 0.95 between dry matter content and starch content. Safo-Kantanka and Asare (1993) reported that tuber dry matter could only explain 40% of variation in starch yield in cassava. The range of values of 25 – 27% and 23 – 28% were obtained for Nkabom and IFAD, respectively. Starch quality, is dependent on the solubility, swelling power and water binding capacity (Baafi, 2005). Poultry manure produced the highest fresh shoot weight and also gave the highest tuber yield. This means that, good vegetative development leading to adequate accumulation dry matter will lead to higher yields. However, this, also depends on dry matter partitioning characteristics of the variety.

5.4 Dry matter and Cooking quality

The result in Table 4.11 showed that poultry manure gave the highest dry matter for Nkabom and TM21 for IFAD. Dry matter content depends on the accumulation of assimilate to the sink from the source which increases with age. This means that farmers over the years have been using dry matter as an index for cultivating particular varieties that suit their food needs for fufu, ampesi and others. Farmers over the years have attached importance to dry matter content either by their own effort or through breeding have selected high dry matter varieties for cultivation. In Table 4.12, poultry manure and TM21 recorded the best cooking quality. This means that the higher the dry matter, the better the cooking quality. There was a positive relationship between dry matter and cooking quality (mealiness). This results agree with the observation made by Safo-Kantanka and Asare (1993) who found positive correction between dry matter content and cooking quality of cassava. A similar observation was earlier made by Safo-Kantanka and Owusu Nipa (1992).

CHAPTER SIX

SUMMARY AND CONCLUSION

CONCLUSION

The findings of this study were:

1. The tuber yield of cassava was significantly increased when adequate nutrients were provided.
2. The cooking quality of cassava tubers is not reduced when fertilizers are applied to the crop
3. Some soil – borne pathogens such as *Fusarium Sp.* can be controlled by the application of Terramend 21
4. Terramend 21 will be an efficient soil rejuvinator if adequate organic matter is provided.
5. There was a positive correlation between tuber dry matter and starch content, tuber mean weight and tuber yield, tuber dry matter content and tuber yield. A negative correlation existed between number of tubers/plant and tuber mean weight.
6. Farmers should use soil amendments particularly poultry manure if available to increase cassava yield.
7. Cassava consumers especially those who use cassava for "fufu" should accept cassava treated with fertilizers as these have no negative effect on the mealiness of the cassava tubers.

RECOMMENDATION

1. The study needs to be repeated to validate the use of Terramend 21 as a control for soil – borne pathogens.
2. Similarly, the experiment needs to conducted on the same plot arrangement for at least three years to allow microorganism to build up in plots treated with TM 21.

3. Adequate organic matter should be added to the soil to assess the usefulness of Terramend 21 in improving the soil's environment. This is because TM21 is not a fertilizer but depends on the availability of a suitable organic material to be effective.

4. An application of NPK 60 – 40 -40 kg/ha + Terramend 21should be applied as a treatment in addition to the half rate of 30 -20 -20kg/ha to compare the effect.

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