KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

INFLUENCE OF RATES AND TIME OF NPK FERTILIZER APPLICATION ON CASSAVA (*Manihot esculenta Crantz*)

BY

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SEPTEMBER, 2015

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST), KUMASI, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRONOMY

BY

BRIGHT ATTA BOATENG

SEPTEMBER, 2015

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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ABSTRACT

The influence of rate and time of NPK fertilizer application on cassava were studied at the research field of CSIR-Crops Research Institutes (CRI) at Fumesua, Kumasi. The experimental design employed was a 4 x 3 factorial experiment with 3 replications. The two factors studied were rate of NPK (15 – 15 – 15) fertilizer and the levels were 0, 200, 400 and 800kg/ha. The second factor was time of fertilizer application which were: 8, 16 and 24 WAP. The treatments were arranged in Randomised Complete Block Design (RCBD). The variety studied was Ampong, an improved cassava variety from the Crops Research Institute.

The results shown that, all the fertilizer treatments resulted in greater growth, measured on plant height and canopy spread. Again, fertilizer treatments resulted in greater number of roots/plant ranging from 4.33 to 6.50 with the 400kg/ha recording the greatest which was significant ($P<0.05$) to the control only. Similarly, fertilizer application improved yield ranging from 23.0 to 36.0 t/ha and the highest yield obtained by the 400kg/ha treatment which was significantly ($P<0.05$) higher than the control. In addition, fertilizer application did not affect ($P>0.05$) root quality factors including tuber shelf life at 7 days after harvesting. Finally, time of fertilizer application did not affect ($P>0.05$) cassava growth, yield and other parameters studied.

Among the fertilizer rates, the 400kg/ha gave the best growth and root yield. Indeed, there appeared to be negative effects of fertilizer beyond this rate. The most profitable treatment was the 400kg/ha and that, if farmers would apply fertilizer, it will enhance growth, root yield and income levels of farmers.

ACKNOWLEDGEMENT

My profound gratitude goes to God Almighty for His divine protection and strength given me during my studies.

My appreciation also goes to my supervisor Dr. Joseph Sarkodie-Addo, Senior Lecturer Department of Crop and Soil Sciences, Faculty of Agriculture and my Cosupervisor Dr. Joe Manu-Aduening of Crops Research Institute, Fumesua – Kumasi for their guidance, constructive criticisms and selfless dedication toward the work hence successful completion of this programme.

I also wish to acknowledge the contributions made by Dr. Ruth Naa Ashiokai Thompson at Crops Research Institute and the entire staff of Root and Tuber Section of Crops Research Institute for their support during data collection.

I am highly indebted to the West African Agricultural Productivity Programme (WAAPP) and Ministry of Food and Agriculture (MOFA) for providing the financial assistance for my programme without which it would have been very difficult to complete this programme. Also give thanks to Mr. Emmanuel Asante Krobea, Director of Crop Services, Ministry of Food and Agriculture (MOFA) and Mr. George Prah, Ministry of Food and Agriculture (MOFA) for their kind advises given me during my studies.

Many thanks goes to my dear wife Mrs. Elizabeth Mengya for her support, contributions and prayers for successful completion of this programme.

Lastly to all whose efforts contributed to the successful completion of this thesis, I say may God richly bless you all. Amen.

DEDICATION

This work is dedicated to my dear wife Mrs. Elizabeth Mengya and our lovely son Bryan Atta Boateng.

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CHAPTER ONE

1.0 INTRODUCTION

Cassava (*Manihot esculenta* Crantz) was introduced from Brazil, its country of origin to the tropical areas of Africa, the Far East and the Caribbean Island by the Portuguese during the 16th and 17th centuries (Jones, 1959). In Ghana, the Portuguese grew the crop around their trading ports, forts and castles and it was a principal food eaten by both Portuguese and slaves. By the second half of the 18th century, cassava had become the most widely grown and used crop of the people of the coastal plains (Adams, 1957).

The Akan's name for cassava 'Bankye' could most probably be a contraction of 'Aban kye' meaning gift from the castle (Manu-Aduening *et al.,* 2005) and the Ewe name 'Agbele' meaning there is life (Allotey *et al.,* 2012) . The spread of cassava from the coast to the hinterland was very slow. It reached Ashanti (and Brong Ahafo) and northern Ghana mainly around Tamale in 1930. Until the early, 1980s, the Akans of the forest belt preferred plantain and cocoyam whilst sorghum and millet were the preference in the north. The crop became firmly established in most areas after the serious drought of 1982/83 when all other crops failed completely (Korang- Amoako *et al.,* 1987). Now cassava is grown in the forest, the transition and the guinea savannah zones (MOFA, 2003).

Cassava is often seen as a "security crop" (Sarma and Kunchai, 1991), or a "famine reserve crop" (Cock, 1985) for several reasons. It can adapt to diverse climatic conditions, as shown by its broad geographical distribution within the lowland tropics between 30° N and 30° S at elevations that range from sea level to 2000 m near the equator.

Cassava can survive long dry periods and be harvested on a flexible schedule, from six months to three years after planting according to varieties and environments.

In Ghana, cassava is cultivated as a monocrop or intercropped with other food crops, either as the dominant or subsidiary crops. In terms of quantity produced, cassava is the most important root crop in Ghana followed by yam and cocoyam. Cassava ranked second to maize in terms of area planted (MOFA, 2009).

The production and worldwide trend is positive over the years and its production level had increased by 12.5% between 1988 and 1990 with Nigeria being the largest producer in the world (MOFA, 1995). At present, more cassava is grown outside its original area of domestication than within. The estimated world production area (15.5 million ha in 1988)-located mainly in developing countries-is more predominant in Sub-Saharan Africa (57%) than in Asia (26%) followed by Latin America (17%) (ElSharkawy, 1992).

Cassava is an important starchy staple crop in Ghana with per capita consumption of 152.9 kg per year (MOFA, 200 9). The production of cassava in Ghana ranged from 10,217,929 MT to 12,260,330 MT in the period 2007-2009 covering an area of 800,531ha to 885,800ha Ghana currently produces about 12,260,000 MT of cassava annually. Out of this 8,561,700 MT is available for human consumption while national consumption is estimated at only 3,672,700 MT resulting in a surplus of about 4,889,900 MT (MOFA, 2009).

Cassava occupies an important position in Ghana agricultural economy and contributes about 46% of the agricultural GDP of the country. Cassava account for daily calories intake of 30% by Ghanaians and is grown by most farming family (MOFA, 1995).

Apart from being cultivated for food, cassava is very versatile and its derivatives and starch are applicable in many types of products such as foods, confectionary, sweeteners, glues, plywood, textiles, paper, bio-degradable products, mono-sodium glutamate and drugs. Cassava chips and pellets are used in animal feed and alcohol product, the leaves serves as food to man and feed for livestock. Cassava is now used in the brewery industries to brew cassava beer. The crop is rich in carbohydrates, calcium, vitamin B and C and essential minerals. However, nutrient composition differs according to variety and age of the harvested crop, soil condition, climate and other environmental factors during cultivation. With the increasing human population and urbanization, the demand for agricultural products has increased with land becoming a limiting factor.

The traditional system of shifting cultivation in most developing countries including Ghana is giving way to continuous system of cropping on the same land resulting in gradual depleting of soil fertility and low crop yield. Harsh climatic conditions have also contributed to the declining soil fertility in developing countries (Henao and Baanante, 1999). Fallow period has been decreasing in the wake of population pressure on farm lands and the need for adequate fertilization to safeguard high cassava yield cannot be over emphasized.

For most crops, the best fertilizer types, rates and time of application are not known and that, this constitutes major constraints to fertilizer use in the country (Sarfo *et al.,* 1998). Mineral fertilizers are scarcely used because of their prohibitive high prices. Cassava yield varies from 5 tonnes/ha to 25 tonnes/ha depending on soil fertility.

Quite a number of fertilizer trials have been carried out mainly at the Soil Research

Institute, but the results have yet to be developed into definite recommendations (Ofori, 1970, 1973, 1976; Takyi, 1972, 1974; Cobbina and Thompson, 1987). However, as cassava is usually intercropped or is the last crop in the rotation before the fallow, the crop does most likely benefit from the residuals of fertilizers applied to the companion or preceding crops. Farmers also generally believe that fertilizers reduce the quality of cassava tubers, cooking quality and storage (FAO, 2000).

The solution to decline in soil fertility is for farmers to apply fertilizers to sustain cassava production and therefore proper evaluation and recommendation to farmers is very essential.

The main objective of this work was to determine the appropriate rate and time of applying NPK fertilizer for sustainable yields of cassava.

The specific objectives were;

i. Evaluate the yield of cassava under 4 rates and at 3 different times of NPK fertilization.

ii. Evaluate the effect of rate and time of NPK fertilization on cooking and pounding qualities of cassava.

iii. Evaluate the effect of NPK fertilization on the shelf life of cassava. iv. Determine the profitability of fertilizer application to cassava production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN AND DISTRIBUTION OF CASSAVA

Cassava (*Manihot esculenta* Crantz) is a short-lived perennial shrub which is grown mostly between the latitude 30º N and 30º S, an area which encompasses some of the poorest countries of the world (Bokanga, 1995).

Cassava was domesticated by Amerindians in South and /or Central America (Oslen and Shaal, 1999). Lathrap (1970) estimated that domestication of cassava began 5000 – 7000 BC. The estimates was supported with archaeological findings in the Amazon (Gibbons 1990). By the time the first Europeans reached the New World, the crop was already cultivated in all of neotropical America (Patino, 1964). In the 16th century, cassava was introduced to the Congo basin by the Portuguese through trade development between Africa and Brazil. In the 18th century, cassava was introduced to Madagascar and the East Coast of Africa from where it moved inland (Cock and Reyes, 1985). By the end of the 19th century, cassava was well distributed throughout lowland tropical Asia and Island of Oceania (Cock and Reyes, 1985).

In Ghana, the Portuguese grew the crop around their trading ports, forts and castles and it was a principal food eaten by both Portuguese and slaves. By the second half of the 18th century cassava had become the most widely grown and used crop of the people of the Coastal Plains (Adams, 1957).

Cassava became firmly established in most areas after the serious drought of 1982/83 where all other crops failed completely (Korang-Amoako *et al.,* 1987). No wonder, the crop is adapted to areas that experience a long dry season and uncertain rainfall, thus qualifying as the crop of choice for drought-prone areas (Cock, 1985).

2.2 TAXONOMY AND MORPHOLOGY OF CASSAVA

Cassava belong to the class dicotyledonae, characterized by the production of seed with two cotyledons, to the subclass arhichlamydeae which is differentiated by the little-evolved perianth, to the order Euphorbiales, family Euphorbiaceae, tribe Manihotae, genus Manihot and species *Manihot esculenta* Crantz. The order euphorbiales is best represented by the great Euphorbiaceae family which is made up of over 7200 species (CIAT, 1984).

The Euphorbiaceae family include plants of different growth habits such as trees, shrubs and grasses. Some are of economic importance as they produce latex (*Hevea brasilensis*), oil (*Ricinus comunis*), edible roots (*Manihot spp*.) and ornamentals (*Euphoria spp*.) (Ekanayake *et al.,* 1997; Fregene *et al.,* 2006). The most important tribe within the Euphorbiaceae family is Manihotae and represented by the genus Manihot. The Manihot genus are about 100 species. *Manihot esculenta* Crantz is the only cultivated commercially (Rogers and Appan, 1973; Onwueme, 1978; Mkumbira, 2002; Nassar, 2006).

Cassava is a perennial woody shrub mainly cultivated for its starchy tuberous roots. It is propagated mainly from stem cuttings (IITA, 1990; Hallack, 2001). Propagation of cassava by seeds occurs under natural conditions and is widely used in breeding programmes (Iglesias *et al.,* 1994).

However, naturally occurring seedlings may be used by farmers as propagated material (Okai, 2001; Kizito *et al.,* 2005; Manu-Aduening *et al.,* 2005).

A mature cassava plant can reach a height between 1- 2m high. However, some cultivars can go as far as 4m (Onwueme, 1978; Ekanayake *et al.,* 1997; Hershey, 2005). According to Onwueme (1978) cassava can be harvested within 1-2 years and can grow for years.

The mature stem is cylindrical with a diameter varying from 2 to 6 cm, both the thickness and the colour varies with the age of the plant and the variety (CIAT, 1984).

The stem cuttings begin to sprout and root within a week after planting. According to Ekanayake *et al* (1997) and Alves (2002) seeds (Seedlings) propagated cassava takes longer, smaller and weaker than plants produced from stem cuttings. Osiru *et al* (1997) reported that stem cuttings from same parents are genetically uniform while seedlings differs genetically owing to outcrossing in cassava. Cassava shoot lengthens and the roots begins to spread within the first two weeks of emergence or sprouting. Tuberisation or root thickening begins about 8 weeks after planting (Ekanayake *et al.,* 1997).

The stem produces two distinct types of branching. The reproductive branches and the lateral branches. The reproductive branches can be seen in a form of dichotomous, trichotomous and tetrachotomous and they are induced by flowering (CIAT, 1984).

Depending on time of first branching, cassava is classified as being early or late branching. Some varieties can branch at 20cm while others never branch and never flower (Hahn *et al.,* 1977).

The lateral branches occurs at irregular intervals and depend on the plant population per hectare, climatic conditions and the cultivar. They are formed from the axillary buds of the leaves of the main stem. The angle produced by the stem are seen as decumbent or horizontal and erect and are mainly under the influence of genetic and environmental factors (CIAT, 1984).

The leaves of cassava are arranged spirally on the stem (2/5 spiral) with long petioles subtended by small deciduous stipules. They are usually dark green but red, yellow and various shades of purple pigmentation occur in the foliage (IITA 1990). The shape of the lobes varies from obovate, elliptic lanceolates, linear (straight), obovatelanceolate, pandurate and arched. However, most cassava varieties grown in Africa are that of elliptical or lanceolate (Onwueme, 1978; Okai, 2001).

The development of the first true leaf marks the start of active photosynthesis when cassava is propagated. The leaf approaches its maximum size between 4-5 months after planting depending on variety (Ekanayake *et al.,* 1997).

Cassava is monoecious with both male and female flower located on the same plant and predominantly outcrossing (Fregene *et al.,* 1997). Flowering may begin as early as the 6th weeks after planting (Jennings and Iglesias, 2002). The male flowers occur near the tip while female flowers develop close to the base of the inflorescence. The female flowers open about 1 – 2 weeks before the male flower on the same branch which enhanced cross pollination. However, self-pollination occurs when female and male flowers located on different branches of the same plant or ranch opens at the same time (Onwueme, 1978; Osiru *et al.,* 1996; Jennings and Iglesias, 2002).

Pollination is usually carried out by insects such as bees and wasps (Onwueme, 1978; IITA, 1990; Mkumbira, 2002).

Cassava produces adventitious root initially which develop into fibrous root and serves as absorption of water and nutrients from the soil (IITA, 1990). The tuberous roots begin to form two months after planting. This happens when few of the fibrous roots start to bulk and become tuberous roots (Alves, 2002).

The rest of the fibrous roots remain thin and continue their function as water and nutrient absorption while the tuberous roots no longer absorb both water and nutrients but receives assimilates from the plant to carry it main function as storing of assimilates (Alves, 2002). As tuberisation continues, tuberous root enlarged due to accumulation of starch (Alves, 2002). The tuberous roots varies in shape from cylindrical, conical, fusiform to cylindrical-conical depending on the soil conditions under which the plant grows (CIAT, 1984). The roots are commonly unbranched and are about 50cm long and 10cm in diameter, but if they are more than metre long, branching may occur (Cobley, 1976). Additionally, the root of cassava can vary in size from 15 to 100cm and from 0.5 to 2.0kg in weight (Meridian Institutes, 2009). A mature tuber consist of three distinct anatomical regions the outer skin or periderm which seals off the surface of the root, a thin rind or cortex usually white, but may be tinged pink or brown and the core or pith (flesh) which consist mainly of parenchyma rich in starch with few xylem bundles and latex tubes usually white but may be yellow or tinged red; this is the edible portion (IITA, 1990).

Cassava roots have the shortest post-harvest shelf life compared to any of the major root crops (Ghosh *et al.,* 1988). The roots of cassava are highly perishable and tend to deteriorate within 24-72 hours after harvesting due to rapid physiological deteriorating processes (Wheatley and Chuzel, 1993)

2.3 GROWTH REQUIREMENTS

Cassava is a plant of tropical lowlands. Its production is found a regions between the latitude 30oN and 30oS (Bokanga, 1993). Cassava finds the most favourable growing conditions in humid-warm climate at temperature between 25oC – 29oC and rainfall between 1000mm – 1500mm which should be evenly distributed (Onwueme, 1978). In terms of climate, cassava has the ability to adapt enormously to varied conditions. In areas with high temperature fluctuations, the temperature must be around 20oC with low temperature fluctuations areas of 17oC sufficient for successful cultivation of cassava (Cock, 1985).

Cassava grows best in areas with deep loamy soils to light sandy soils (RTIMPMOFA, 2009). These soils should be rich in nutrients, low in gravely/stones, hold water well and are easy to work or till. Sandy/stony and clayey soils are not the most suitable soils for growing cassava as they do not allow the root to expand (RTIMPMOFA, 2009).

The crop does tolerate pH range of 4.0 – 8.0 (Stephen, 1995). In terms of topography, the best form of farmland for cassava production is flat or gentle sloping lands. Steep slopes are easily eroded and are therefore not very good areas for growing cassava.

Valleys and depression areas are also not very suitable because they usually get waterlogged and do not allow cassava roots to develop well (IITA, 2000).

2.4 PLANTING MATERIALS

Cassava is mostly cultivated by means of stem cuttings (IITA, 1990; Hallack, 2001). However, it can also be propagated by seeds which occur under natural conditions and widely used during breeding programmes (Iglesias *et al.,* 1994).

Most farmers obtain planting materials from their own farms, other farmers' farms, village markets, roadsides and few farmers occasionally obtain planting materials from research and extension stations (RTIMP-MOFA, 2009). In Ghana as in most of Africa, landraces bred by farmers are the main sources of production (COSCA, 1999).

The choice of good planting material is the basis for good cassava production. Stem cuttings (sticks) are obtained from healthy, disease free and vigorously growing plants. It is not advisable to select stem cuttings from immature stems (top green stems) and old plants (over 2 years) (RTIMP-MOFA, 2009). Cuttings from immature stems are susceptible to pathogens, insects and cannot be stored for a long time because they dry rapidly. Stem cuttings from older plants/stems are lignified and contains only small amount of nutrients for sprouting and sprouts are weak (Ekanayake *et al.,* 1997).

Stem cuttings are obtained from the middle portion of the stem and are cut into a length at 20 – 25cm long with 5 – 7 nodes (RTIMP-MOFA, 2009). Cuttings should be done only when you are ready for planting. Stems are cut with a well-sharpened machete, knife, cutlass or circular saw.

There is the need to avoid rough handling during cutting otherwise, the epidermis and buds may be bruised or damaged as each wound provides entry for microorganisms (Ekanayake *et al.,* 1997; RTIMP-MOFA, 2009).

The stems cuttings can be treated with appropriate pesticides by immersing the stems for about 5 minutes and drying them in the shade. The use of pesticides is not common among cassava farmers in Africa (Ekanayake *et al.,* 1997).

Pre-planting of stem cuttings before planting lead to improvement of establishment particularly in the humid and sub humid regions. Other advantages of pre-planting of stem cuttings are high vigour, a full crop stand, reduced weed pressure and higher yields (Ekanayake *et al.,* 1997). Pre-planting are done by placing the stem cuttings into a perforated polyethene bags without soil usually clear bags. The bags are then filled to

2/3 with the cuttings leaving 1/3 space on top for aeration. The bag is tied with a piece of string and placed in a shaded area or under a roof. Sprouting appears in 3 – 5 days. However, some varieties require a longer period for sprouting (Ekanayake *et al.,* 1997).

2.5 MODE OF PLANTING

The time for planting cassava differs according to the season and the agro ecological zones. In zones with bimodal rainfall pattern, cassava can be planted at the beginning of the major growing season (April – May) or at the minor growing season (August). In the savanna zones, cassava can be planted at the beginning of the major season (May – June). In general, planting date recommendations should fit within the local farming calendar (RTIMP-MOFA, 2009).

The stems are packed in bundles of 50 with each bundle having 50 stems at 1m long and tie for transportation. This gives total plant population at 10,000 plants per hectare when planted at 1m x 1m. However, it is advisable to treat stem cuttings against infections using a broad spectrum fungicides and insecticides such as Benlate (fungicide) and Perfeskthion (insecticides) (IITA, 2005).

Cassava cuttings can be planted either vertically, at an angle (inclined) or horizontally, depending on soil types. The drier the soil, the bigger the part of stem placed in the soil. The vertical planting method is best suitable in sandy soils and consists of planting the cuttings vertically with two-thirds of the length of the cutting below the soil. Planting at an angle is most suitable in loamy soils and consists of planting the stem cuttings inclined with an angle ranging from slightly above horizontal to about 45°. Horizontal planting is recommended for dry climates and consists of placing the entire stem cutting horizontally in the soil at a depth of about 5 to 10 cm (Agric guide, 2014). The cuttings can be planted either on flat lands, on mounds or on ridges depending on the nature of the land. It is recommended to plant on ridges or mounds in waterlogged areas to prevent root rot as cassava does poorly in waterlogged areas. However, improper planting method could make plant lodge, produce small roots and difficult to harvest (IITA, 2005).

The spacing between the cassava plants depends on several factors such as the variety used, the soil type, soil fertility, water availability and whether cassava is grown alone (monocrop) or with other crops (intercrop) (IITA, 2005).

If cassava is being grown alone, it is recommended to plant at 1m x 1m for the branching varieties (IITA, 2005; RTIMP-MOFA, 2009) and at 1 x 0.8m for the nonbranching varieties (IITA, 2005). However, for intercropping it is recommended to plant at a wider spacing of 1 x 1.5m for the branching varieties and at 1 x 1m for the non-branching varieties (IITA, 2005).

Adherence to planting distance are key in cassava production as too wide spacing between cassava plants leads to increase in weed competition and poor yield per unit area (IITA, 2005; RTIMP-MOFA, 2009).

2.6 COMMON WEEDS AND CONTROL

Weeds can reduce cassava yields by competing with the cassava crop for moisture, nutrients, space and light. Slow initial development of stem cuttings/sprouts makes cassava susceptible to weed competition in the first 3 to 4 months. Weeds may also harbour pests and diseases or physically injure cassava plants and root tubers. For these reasons, close attention should be paid to weed control in the field in an effort to grow a healthy crop and obtain high yields of cassava (Organic Africa, 2011). It is recommended to weed cassava farm when plants are 20cm – 25cm tall within 3 – 4 weeks after planting. Second weeding is recommended at one or two months after the first weeding (IITA, 2000).

In Africa, common weeds in cassava production can be broadly groups as grasses, sedges and broadleaf weeds (IITA, 2000).

Grasses such as the spear grass (*Imperata cylindrica*), guinea grass (*Panicum maximum*), bermuda grass (*Cynodon dactylon*) and the feathery pennisetum (*Pennisetum polystachion*) are the most commonly found in cassava production (IITA, 2000)

Sedges resemble grasses but are erect with solid and triangular shaped stems. The common sedges in cassava production are the *Mariscus alternifolius* and the purple nutsedge (*Cyperus rotundus*) (IITA, 2000).

The most commonly broadleaves weeds found in cassava farms include the siam weed (*Chromolaena odorata*) known in Ghana as Akyeampong, wild poingettia (*Euphorbia heterophylla*), giant sensitive weed (*Mimosa invisa*), tridax (*Tridax procumbens*), goat weed (*Ageratum conyzoides*), waterleaf (*Talinum triangulare*) and the tropical spiderwort (*Commelina benghalensis*) (IITA, 2000).

According to Ekanayake *et al.* (1997), management of weeds in cassava farms involves the adaption of measures such as cultural, which mainly involves hand weeding using simple farm tools such as hoes, cutlasses etc. However, this is effective on small farms and is common among small-scale cassava farmers. Farm lands fallowed for more than 5 years are cleared and weed at 3, 8, and 12 weeks after planting.

The biological measures involves the use of live mulch (*in-situ*) in the form of a cover crops which helps in suppression of weeds.

Planting of *Mucuna pruriens var. utilis* prior to cassava cultivation helps, weed suppression. Appropriate intercropping specifically with leguminous species reduces weeding frequency significantly and improves soil improvement.

Weeds can be controlled by planting improved cassava cultivars that are vigorous, able to cover the ground rapidly and are more competitive against weeds. Slowgrowing and late-branching cultivars are less competitive against weeds.

In addition weeds can be controlled by using several pre-emergence and post emergence herbicides. Chemicals such as chloramben (1-3kg/ha), diuron (1-3kg/ha), formulated mixtures of fluometuron and metalachlor (2+2kg/ha), metabromuron and metalachlor (4kg/ha), fluometuron and pendimethalin (2+2kg/ha) and primextra (premix of atrazine + metolachlor) (2-3kg/ha) have been recommended. In Ghana, herbicides such as alachlor (lasso), atrazine + metolachlor (primagra/primextra) and atrazine + alachlor (lasso/llariat) are recommended as pre-emergence herbicides for cassava production (RTIMP-MOFA, 2009). Ekanayake *et at.* (1997) reported that herbicides are more effective if applied before weeds infest a field, cost effective when available in appropriate quantities and when fields are too large to be weeded by hand. Integrated weed control can be used by employing combinations of any of the four methods.

2.7 CASSAVA FERTILIZATION

Cassava does very well on poor soils as compared to other crops. The cassava crop is highly responsive to fertilization. According to FAO (1999) cassava responds highly to fertilizer application as other crops with yield increase of 49% in West Africa and up to

110% in Latin America. Yields of cassava can be improved and sustained through the application of appropriate amount of inorganic or organic fertilizers (manure).

According to Vanlauwe (2012) cassava yield increased from 12 to 25 t/ha when moderate level of NPK was applied to the crop and yield increased more than 40 t/ha when higher rates of NPK was applied.

FAO (2013) recommended that cassava should be fertilized initially with equal amount of N, P_2O_5 and K_2O at a rate between 500kg to 800kg/ha of a compound fertilizer such as 15 – 15 – 15 or 16 – 16 – 16. However, the NPK levels need to be modified to compensate for the nutrient loss through root harvest when the crop is grown continuously on that same land. Agbaje and Akinlosotu (2004) reported significant reduction in root yield of cassava when fertilized with 400 and 800 kg NPK per hectare and that number of roots per plant and root rot were not influenced by fertilizer application. It is recommended that in Ghana 400kg of NPK (15 – 15 – 15)/ha or 40g/plant be applied to the crop and that the application be split with first application when the plant is at 30 DAP and second application at 60 DAP (Lebot, 2009; Ibia and Udo, 2009). MOFA (2009) reported that NPK (15 – 15 – 15) should be applied at 200kg/ha or 20g per plant and be split at one month after planting and four months after planting. However, Howeler (1990) reported no significant differences between a single applications at 30 DAP and split application at 30 and 60 or at 30, 60 and 90 DAP.

Cassava responds sensitively to over fertilization, particularly to N, which lead to excessive leaf formation at the expense of root development. Adequate K levels in soil stimulate response to N fertilizers but excess amount of these nutrients leads to luxuriant growth at the expense of root formation (Sanchez, 1976; Onwueme and Charles, 1994).

Cock (1975) reported that optimum leaf area index (LAI) of cassava ranges between 2.5-3.1 and high rates of fertilization may lead to excessive leaf growth.

Application of high levels of N would not only affect harvest index (HI) and root yield, but reduces the starch and increase Hydrogen Cyanide (HCN) content of roots. Generally, nutrients are in interactions with each other and application of excess of one nutrient, may cause a deficiency in the other. Hagens and Sittibusaya (1990) reported that in 100 NPK trials carried out by FAO on the field of farmers in Thailand, cassava responded to fertilizer in the order of N, K and P. In Africa relatively few fertilizer trials have been conducted, mainly because very few cassava farmers apply fertilizer to the crop. In a survey conducted by Tettey and Frimpong (1991), they reported that farmers in Ghana do not apply fertilizer to the plant because they perceived that cassava does not require fertilizer, it affects the quality of the root and finally affects the shelf life of the root (root rot fast at storage).

According to Okugun *et al.* (1999) cassava responds greatly to N in West Africa. Krochmal and Samuels (1970) reported high N application leads to 41% reduction in roots yield and 11% increase in top growth. High rates of N induces the production of compounds that are high in N, like protein and HCN which may lead to decrease in starch content in roots. Howeler (1985) reported no significant differences between single application of N rates at 200kg/ha at one MAP when accessing the optimum time and partitioning of N. Higher yields of cassava had been reported with slow releases of N (Vinod and Nair, 1992). Cassava can produce yields between 40 – 50t/ha without the application of P CIAT (1988). Takyi (1972) reported that, cassava responds positively to P application in Ghana.

However, on forest ochrosol in Ghana cassava responded negatively to P application (Ofori 1973b). The ability of cassava to grow on low P soils depend largely on varietal differences (CIAT, 1988). However, varietal differences to P applications is not caused by genetic differences in uptake of P, but caused by differences in distribution of dry matter and efficiency of P use (Pellet and El-Sharkawy, 1993). Cassava varieties that tolerate low levels of P shows a fine root length density, moderate top growth and a high stable harvest index.

Application of potassium enhances the net photosynthetic ability per leaf area and promotes the translocation of photosynthate to the roots. The application of potassium promote better root yield as well as starch content. Application of 80-100kg/ha of K_2O increases the starch content of cassava roots and then drops at higher rates of K application. Obigbessan (1973) and Kabeerathumma *et al.* (1990) reported that application of K, may lead to a reduction in HCN content of roots. On the contrary Payne and Webster (1986) reported higher levels of HCN in roots produced on low K soils.

According to CIAT (1982) there is no difference between single and split applications or among different times of K application, however, single application at one MAP produced the highest yield.

Howeler (1980) reported that, manure are low in nutrient usually, less than 10% of what is found in inorganic fertilizers but are rich in calcium, magnesium, sulphur and other micro-nutrients found in inorganic fertilizers. Silva (1970) reported that, cassava shows good responses of 6-15t/ha of cattle manure. Howeler (1985) reported that yield of cassava can reach between 19 to 33t/ha when chicken manure is applied at 4.32t/ha.

The practicing of ‘parcagem’ principles which involves the application of cattle manure *in-situ* resulted in high yield of cassava (Gomes *et al.,* 1983). Under this principles 30 cattle are kept overnight on one hectare of land for a period of 60 days and about 8 tons of manure, containing 40kg N is produced. Addition of P and K to increased yield of cassava to about 30-90% as compared to inorganic fertilizers. Diniz *et al.* (1994) reported positive results when cattle manure was applied at 5t/ ha with 10kg P_2O_5/ha.

Sittibusaya (1993) reported that cassava yields dropped from 30-26 to 12-10t/ha after twenty years of cassava cultivation without fertilization. Application of NK or NPK and adequate fertilization, yields of cassava can be sustained at about 20t/ha for a period of years under continuous cropping.

2.8 COMMON PESTS AND THEIR CONTROL

Cassava is vulnerable to pests that can cause heavy yield losses. In some regions, the incidence of pests is increasing as the crop is grown more intensively over larger areas and planted throughout the year for industrial processing.

The cassava mealybug (*Phenacoccus manihoti*) is commonly found at cassava shoot tips, on the under surfaces of leaves and on stems. The cassava mealybug sucks sap from cassava leaves and shoots tips. The mealybug injects toxin into the cassava plant through its feeding, thereby causing deformation of terminal shoots, which become stunted, resulting in the compression of terminal leaves into "bunchy tops" (Braima *et al.,* 2000).

The damage is more severe during the dry season as compared to wet season (Braima *et al.,* 2000). At severe stage, plants die from the plant tip, where mealybugs are mostly found (Infonet-biovision, 2015). FAO (2013) reported that, yield loss in infested plants can be as high as 60% of the roots and 100% of the leaves.

FAO (2013) recommends the use of locally recommended chemical control measures in handling cassava mealybugs. Other recommendations involving cultural measures such as early planting of the cassava crop, as infestation is more severe during the dry season and hot water (mixing equal volumes of boiled and cold water) treatment of cassava planting materials by immersing the cuttings for 5-10 minutes just before planting. It helps in killing insects and avoid transfer to newly planted fields. The application of manure or other fertilizers helps in the reduction of mealybug population, as improved nutrition leads to the production of larger parasitoid wasps with higher fertility levels. In addition, mulch and fertilizer enhances the antibiotic properties of cassava against mealybug infestation (Infonet-biovision, 2015).

Cassava mites (*Mononychellus tanajoa*) are important insect pest in all producing regions. They cause the most damage to cassava in Latin America and sub-Saharan Africa, especially in lowland areas with a prolonged dry season. Cassava plants are more vulnerable to green mite infestation at 2 to 9 months (Infonet-biovision, 2015). The insect feeds on the underside of young leaves, which become white-yellow, deformed and smaller (FAO, 2013). Severe attacks causes the terminal leaves to die and drop and the shoot tip looks like a "candle stick" (Infonet-biovision, 2015).

Cassava green mite can cause root yield losses between 20 - 80% (FAO, 2013). According to FAO (2013) and James *et al.* (2000) cassava green mite can be controlled by planting varieties that are resistant or tolerant to the mite, treating planting materials with locally recommended insecticides before planting, early planting to ensure good plant population, applying adequate and well-balanced fertilizers to improve plant vigour. To reduce mite population, application of foliar sprays with water at high pressure and strictly enforcing quarantine regulations have been recommended (FAO, 2013).

Ezulike and Egwuatu (1993) reported that cassava green mite effect on cassava plant is reduced when cassava is planted with pigeon pea than without pigeon pea in Nigeria and higher root yields were obtained when cassava was intercropped with pigeon pea in triple and double rows than when it was alternated in a single row or in a pure stand.

African cassava farms are prone to two grasshopper species namely the variegated grasshopper *Zonocerus variegatus* mostly found in the West and East Africa south of the Sahara and the elegant grasshopper *Zonocerus elegans* commonly found in Southern Africa and East Africa (Infonet-biovision, 2015). The insect chew cassava leaves, petioles and green stems. It's feeding leads to defoliation of the plants and debarks the stems.

The pest damage is more common on older than on younger cassava plants and is more severe in the dry than in the wet season (Braima *et al.,* 2000). On smaller fields, the insects can be controlled by hand picking, digging and destroying, laid eggs before they are hatched in the dry season. However this is possible only when the field is small (Infonet-biovision, 2015).

Nicol *et al.* (1995) and Olaoifa and Adenuga (1988) reported that Neem extract help in protecting cassava from grasshopper damage. The extract serves as anti-feedant which prevent the grasshoppers from feeding on the cassava when exposed to the Neem products.

Olaoifa and Adenuga (1988) reported that, the application of emulsifiable concentrate of Neem oil at 0.5% to 2% applied at 8-day intervals or at 3-4% at 10-day intervals and aqueous Neem kernel water extracts (NSKE) at 7-10% applied every 12 days and aqueous Neem leaf water extracts (NLWE) 50% applied every 6 days resulted in good control of *Z. variegatus* on cassava in Nigeria.

Different species of whiteflies are found on cassava in Africa and the two most important are the spiral whiteflies (*Aleurodicus dispersus*) and the tobacco whiteflies (*Bemisia tabaci*). Some whiteflies cause major damage to cassava as vectors of cassava viruses. The spiraling whitefly (*Aleurodicus dispersus*) was reported as a new pest of cassava in West Africa in the early 90s (Infonet-biovision, 2015).

The tobacco whitefly (*Bemisia tabaci*) transmits the African cassava mosaic virus, one of the most important factors limiting production in Africa. The insect suck sap from the leaves as it feeds but does not cause physical damage to the plant. The insects inject the plant with viruses which cause cassava mosaic disease, making them important insects in cassava production (Braima *et al.,* 2000).

Several species of termites damage to cassava stems and roots. Termite damage are mostly observed during the dry season and on late planted fields, particular when the crop is still young at the peak of the dry season.

Activities of termites are pronounced as they chew, eat stem cuttings from newly planted cassava farms leading to poor growth, death and eventually rot of affected plants. They are capable of destroying whole cassava field. Termites chew and enter the stems of older pants which weakens the stems and causes them to break easily (Braima *et al.,* 2000). Termites are effectively controlled by adopting cultural practices such as early planting coinciding with the rains and avoiding planting on very dry lands or on termites mounds (Braima *et al.,* 2000).

Braima *et al.* (2000) reported that cassava root scale (*Stictococcus vayssierrei*) are mostly found in parts of Central Africa and are mostly found in the soil and live on the storage roots, feeder roots and submerged stems of cassava. The cassava white scales (*Aonidomytilus albus*) are mainly found on the surfaces of the cassava stem. The insect feeds by sucking sap from cassava stems causing the stem to dehydrate and eventually death of plant (Braima *et al.,* 2000).

The common vertebrate pests of cassava includes birds like bush fowl or francolins (*Francolinus sp.*) and wild guinea fowls, rodents like glasscutters or cane rat (*Thryonomys swinderianus*) and giant rat (*Cricetomys gambianus*), monkeys, pigs and domestic animals (cattle, goat and sheep) (Braima *et al.,* 2000). Their destructive effect on the cassava crop is by feeding on the leaves, stems and the storage roots of the crop (Braima *et al.,* 2000). James *et al.* (2000) suggested early harvesting of cassava roots as soon as they are matured, helps to reduce and prevent cassava roots from being damaged.

2.9 COMMON DISEASES OF CASSAVA AND THEIR CONTROL

Cassava farmers are unable to obtain the optimum yield of cassava, due to numerous diseases that affect the crop. Cassava is exposed to more than 30 pathogens (Nilmanee, 1986; IITA, 1990), which cause various degree of losses (Lozano *et al.,* 1981).

Some of the diseases attacking cassava are so serious that they can give no yield of storage roots if not controlled (RTIMP-MOFA, 2009). RTIMP-MOFA (2009) and Msikita *et al.* (2000) reported that, the major diseases of cassava are the African Cassava Mosaic Disease, Cassava Bacterial Blight, Cassava Anthracnose, Cassava Bud Necrosis and Root rots.

The African Cassava Mosaic Disease (ACMD) is caused by virus and occurs mainly in the leaves and stem of the cassava plant. The virus is spread by whitefly (*Bemisia tabaci*) from infected plants to healthy cassava plants. Infected stem cuttings are sources of contamination if used to plant clean fields (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). In severe attack the leaves become small and shriveled and the plants become stunted (Msikita *et al.,* 2000). Homenauth *et al.* (2011) reported that the virus can be controlled by adhering to strict cultural measures and the use of chemicals such as Admire, Vydate L., Abametin, and Vertimec at the recommended rates, targeting the main transmitting agent, the whiteflies (*Bemisia tabaci*).

Cassava Bacteria Blight (CBB) (*Xanthomonas campestris pv. manihotis*) is caused by bacterium (*Xanthomonas axonopodis pv. Manihotis*) and mostly found in the leaves and stems of the cassava plant. The disease is a major constraint to cassava production in Africa (Infonet-biovision, 2015). Cassava bacteria blight attack the leaves of the cassava plant and its severity is seen in leaves of younger plants.

The disease is more serious in the rainy season as compared to the dry season (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). Infected plants, dead stems, leaves left after harvest, planting of infected stems and the use of infected farm tools during the cutting of sticks serves as the main source of the disease (Homenauth *et al.,* 2011; Msikita *et al.,* 2000).

The disease can be controlled by employing all cultural measures in combination with chemicals such as Fastac, Decis or Karate targeting the insect vector (Homenauth *et al.,* 2011).

The cassava anthracnose disease (*Glomerella manihotis*) is caused by fungus and attack the surfaces of stems and leaves of the cassava plant. The disease appears as cankers (sores) on the stem and bases of the leaf petioles (Msikita *et al.,* 2000). The main transmission of the fungus is by planting infected stakes. However, wind also transmits the spores of the fungus from infected plants to healthy plants (Msikita *et al.,* 2000). Msikita *et al.* (2000) reported that cassava anthracnose disease infestation is controlled by adhering to strict cultural measures.

Cassava Bud Necrosis is caused by fungus and affects mainly the surfaces of the stems and leaves of the cassava plant (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). The fungal spores are found on the buds or the eye on cassava stem or cuttings, resulting in the death of the bud.

The disease reduces the sprouting ability of stem cuttings (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). The disease spread by planting infected stems, remains of infected cassava stems and leaves on the field after harvest and by wind and the recommended control measures are integrated crop management, cultural control and spraying of fields or crops with recommended fungicides (Homenauth *et al.,* 2011; Msikita *et al.,* 2000).

Root rot disease of cassava are caused by living micro-organisms such as fungus and bacteria of various kinds that live on or in the soil (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). The effect of these micro-organisms are severe in poor drain soils (Msikita *et al.,* 2000).

The disease kills both feeder and storage roots of cassava and affected storage roots may or may not swell, rather develop light brown coloration when the roots are cut open and produce an odour due to the rot of the root by the disease (Msikita *et al.,* 2000; Homenauth *et al.,* 2011). Homenauth *et al.* (2011) recommended good farm sanitation, avoiding planting in waterlogged and poor draining soils, planting resistance or tolerant varieties, good cultural measures and use of recommended chemicals for controlling the disease.

Cassava brown streak disease (*Potyvirus-Potyviridae*) is mainly caused by a virus and transmitted by the whitefly (*Bemisia tabaci*) (Homenauth *et al.,* 2011; Msikita *et al.,* 2000). Jameson (1964) reported that cassava brown streak disease as endemic in Tanzania, Kenya, and Mozambique, along the Lakeshore of Malawi, Zanzibar and Uganda and believed to have been introduced to these countries from Amani in 1934 through planting materials. The disease is capable of destroying everything in the field (Msikita *et al.,* 2000). According to Hillocks *et al.* (2001) the effect is very high especially after the physiological maturity of the crop at 12 MAP.

The disease is effectively controlled by using disease-free planting materials, planting resistant varieties and removal and burning of infected cassava plants (Infonetbiovision, 2015).

The leaf spot disease of cassava is caused by fungus. According to Msikita *et al.* (2000) cassava leaf spot are of three different types, the brown leaf spot, the white leaf spot and the leaf blight.

The whitish leaf spot is characterized by whitish or brownish-yellow spot on the upper surfaces of the leaves of infected plants.

The brown spot appear as brown spots surrounded by dark borders on the upper surfaces of infected plant leaves and the leaf blight characterized by light brown lesions on the upper surfaces of the infected plant leaves but do not show watersoaked appearance, as that of the cassava bacteria blight (Msikita *et al.,* 2000). The disease mainly spread by wind or rain which carries the disease from infected to healthy plants. Weeds also serve as alternative hosts for leaf spot fungi. The disease is effectively controlled by adapting measures such as integrated crop management, good cultural measures and spraying with recommended fungicide (Homenauth *et al.,* 2011).

2.10 PRODUCTION LEVELS

Cassava serves as means of livelihood for up to 500 million households, several processors and traders around the world. Cassava is a basic staple for many people in the tropical and sub-tropical belts and as a raw material for numerous industries around the world.

The global production area in 2005 stood at 18 million hectares and out of the total area, Africa accounted for 57%, Asia 18% and 16% in the Latin American and

Caribbean (LAC) with the global production estimated in the same year to be about 208.1 million tones.

Out of this, Africa produced 118.5 million tonnes, 53 million tonnes produced in Asia and 36.6 million tonnes produced by the LAC (Sesrtcic, 2014).

FAO (2012), estimated that more than 280 million tonnes of cassava was produced globally representing an increase of 60% since 2000 with doubled annual growth over the previous two decades. FAO (2013) has reported that, between 1980 and 2011 the world production area increased from 13.6 million to 19.6 million hectares equivalent to 44% and production in the same period was more than doubled from 124 million tonnes to 252 million tonnes.

Production of cassava has increased in sub-Saharan Africa with 140.9 million tonnes more than half of the global harvest in 2010 (FAO, 2013). Production almost doubled from 48.3 million to 95.3 million tonnes between the period of 1980 and 2000, the increase resulted from 56% increase in area harvested and 25% growth in yield (FAO, 2013). The biggest gains in cassava production since 2000 have been in West Africa, where output rose by 60 percent, from 47 million to 76 million tonnes and this was due to the fact that countries in the sub-region see the potential of cassava as an industrial crop, that could help bring income to farmers, earn foreign exchange and generate jobs (Sanni *et al*., 2009).

According to IITA (1997) African cassava production is mainly from Nigeria which accounts for 35% of all produced in Africa, Democratic Republic of Congo with 19%, Ghana 8%, Tanzania 7% and Mozambique 6% of the total African production.

In terms of value, Ghana is the 6th world producer of cassava and from 2005 to 2010 Ghana has remained unchanged in terms of world ranking (Angelucci, 2013). Cassava contributes 22% of Ghana's agricultural GDP and remains one of the main staple crops with annual production in last ten years reaching more than 10 million metric tonnes (Angelucci, 2013).

In Ghana, cassava is the second largest crop to maize in terms of production area (MOFA, 2010). However, with the introduction of high yielding and disease resistant varieties, the yield of cassava has seen some increases up to 15 MT/ha in 2010 but this level is below the achievable yield of 48.7 MT/ha (SRID, MOFA, 2010). In terms of production levels, cassava is the most important crop in Ghana followed by yam, plantain, maize and cocoyam with production levels at 13,504,000 MT, 5,960,000 MT, 3,538,000 MT, 1,872,000 MT and 1,355,000 MT respectively (SRID, MOFA, 2010).

2.11 ECONOMIC IMPORTANCE OF CASSAVA

Cassava roots after harvest are used mainly for household consumption or processed into various kinds of products due to their high deteriorating rates. The potential of cassava roots to remain in the soil after maturation without deteriorating makes cassava a very good food security crop. It is noted that, 88% of cassava produced in Africa is eaten by humans as food and the rest of 20% is processed (Westby 2008). Westby (2008) reported that, cassava consumption is the highest per capita in the world and it provides inexpensive and reliable source of carbohydrates for people in Sub-Saharan Africa.

In terms of calories intake and per capita consumption, cassava becomes the number one crop in Ghana. FAOSTAT (2007) reported that per capita daily intake of cassava is 551grams which amount to 26 % of total per capita daily intake.

In terms of calories, cassava consumption per day per person gives 599 kcal amounting to 20 % of total daily calories' intake. Root and tuber crops such as cassava, yam and cocoyam constitute a major part of staple diet in rural Ghana.

An estimated per capita consumption of 151.4 kg of cassava, 43.3 kg of yam and 56 kg of cocoyam, they account for 58% of the per capita food consumption. Cassava alone account for 34% of food crop consumption per annum and accounting for 22% of the Agriculture Gross Domestic Product (AGDP) (MOFA, 2003).

Cassava starch has high competitive advantage over other industrial starch owing to its unique properties of high viscosity and freezing resistance. Ghana used 5000 tons of starch per annum, out of the total, 40% was used in the textile industries, 27% in plywood industries, 20% in pharmaceuticals, 10% in paper industries and the remaining 10% used in the food industries (Dziedzoave *et al*., 2000).

2.12 FOOD VALUE OF CASSAVA

Cassava is grown principally as food crop, usually cooked or cut into pieces and dried as cassava chips and ground into cassava flour. The commonest method of preparing the fresh root of cassava for consumption in Ghana is by boiling and pounding the cooked roots and mixed with that of either plantain, cocoyam or yam into a thick paste commonly called 'fufu' in Ghana. In Ghana the paste 'fufu' is consumed only with soup. The dried chips of cassava is also milled or ground into flour and prepared into a dark or light brown dough 'konkonte' in a boiling water, mixing the flour with the water and turning till well cooked. The dough 'konkonte' is mainly eaten with soup and less commonly with hot pepper in Ghana.

Eating of boiled fresh sliced roots of cassava (ampesi) is regarded as the food for the poor and is commonly found in households in rural communities in Ghana. Vanhuyse (2012) reported that, out of the total cassava harvested in Ghana, 50% of the fresh root is consumed as 'fufu', 25% used to produce 'Gari' (roasted fermented cassava), 18% used to produce 'Agbelima' (fermented cassava mash), 6% used to produce 'Konkonte' (dried chips), 1% used for industrial purposes.

Ugwu and Ay (1992) indicated similar uses of cassava fresh roots in Ghana as that of Vanhuyse (2012) as cooked fresh roots (that include pounded fresh cassava, known as 'fufu' in Ghana), flour (fermented and un-fermented), granulated roasted cassava (known as 'Gari'), fermented pastes (known as 'Agbelima'), sedimented starch and Bio-ethanol.

Little is reported on the usage of cassava leaves in Ghanaian food as the leaves are rarely used in Ghana as food. The cassava's nutritional value is related to its starch content.

The roots and leaves constitute 50% and 6% of the mature cassava plant, respectively and are the nutritionally valuable parts of cassava (Tewe and Lutaladio, 2004).

Cassava has about twice the calories than that of potatoes and highest among tropical starch rich tubers and roots. A 100g of cassava root provides 160 calories. Calories are mainly produced from Sucrose which account for more than 69% of the total sugars found in the cassava root. Cassava is very low in fats and protein than in cereals and pulses. However, it has more protein than other tropical crops such as yam, potato and plantains (Rudrappa, 2013).

Cassava is principally composed of carbohydrates and it constitutes the largest part of the crops dry matter. The root is relatively good source of some important minerals like zinc, magnesium, copper, iron, and manganese for many people living in the tropical regions. It has high amounts of potassium of 271 mg per 100g or 6% of RDA.

Potassium is an important component of cell and body fluids that help regulate heart rate and blood pressure. The young cassava leaves provide a good source of dietary proteins and vitamin K, which helps in building bone mass leading to the enhancement of osteotrophic activity in the bones.

It also helps in reducing neuronal damage in the brain of patients suffering from Alzheimer's diseases. (Rudrappa, 2013).

The presence of cyanogenic glucosides in cassava in the form of linamarin 93% and lotaustralin 7% identify cassava as either sweet or bitter. The cyanogenic glucosides content in cassava is not uniform as it varies with the part of the plant, its age, variety and environmental conditions such as soil, moisture and temperature (Nartey, 1977).

The cyanide is poisonous to both human and animals at higher levels. This level is often seen at the outer part and peels. However, peeling reduces the cyanide content, sun drying and soaking followed by boiling in salt-vinegar water leads to evaporation of this compound and makes it safe for both human and animal consumption (Rudrappa, 2013).

Gil and Buitrago (2002) reported that, variety and age of root determines the fibre content of cassava root and it does not exceed 1.5% and 4% in fresh roots and root flour respectively.

Cassava contains high amount of vitamin C (ascorbic acid) and ranges between 15 to 45 mg/100g edible portions (Okigbo 1980; Charles *et al*., 2004). However, the roots of cassava contain low levels of the B vitamins and during processing most of these nutrients are lost. Sorghum and maize contain high levels of mineral and vitamin than that of cassava roots (Gil and Buitrago 2002).

Cassava serves as good source of food for both human and animals, ranging from its fresh roots, peels to leaves. Fresh and dried roots (chips) including peels and leaves are all fed to animals ranging from ruminants to non-ruminants.

2.13 STORAGE OF CASSAVA

Cassava is harvested when the crop/roots are physiologically matured usually between 9 – 18 months after planting but can be left in the ground for up to 2 years. In the lack of storage facility, cassava fresh root begins to deteriorate within 3 to 5 days after harvesting (Rickard, 1985). The physical damage caused to cassava roots during activities involving harvesting and handling increase the chances of root deterioration.

Storage of cassava roots can be viewed in two broader perspectives, namely the traditional and modern storage methods (IITA, 1990; RTIMP-MOFA, 2009). Under the traditional methods, the matured cassava crops are not harvested but allowed standing until when needed. This method may result in root becoming fibrous or rotten and reduction in flavor (Lancester and Coursey, 1984; RTIMP-MOFFA, 2009). This practice tie up farm lands which could have been used to grow other crops and is a major problem in areas with limited farm lands (Knoth, 1993).

Cassava root can also be stored in shallow pits under shade and covered with soil, pilling them into heaps and watering daily. Storing the roots in water and all these are done to keep the roots fresh (RTIMP-MOFA, 2009).

The modern methods involve the storing of the roots in trenches lined with palm branches or raffia leaves, storing roots in moist saw dust in paper cartons, baskets or wooden boxes with covers and dipping fresh roots in 0.4% solution of fungicide (Thiabendazole e.g. Mertec) and packing the treated roots in polyethylene bag (RTIMP-MOFA, 2009; Osei-Opare, 1990; Etejere and Bhat, 1986). CIAT (1989) reported that, this method can extend the shelf life of cassava roots from 3 to 4 days to 2 to 4 weeks when used properly.

In addition, cassava roots can be stored in refrigerators at 3°C (Rickard and Coursey, 1981) and coating of cassava roots with paraffin wax helps in extending the shelf life of cassava roots up to 2 months (Knoth, 1993).

2.14 EFFECTS OF FERTILIZATION ON TASTE, POUNDABILITY AND STORAGE OF CASSAVA

Howeler (1991) reported that, cassava is a heavy nutrient feeder, removing about 55 kg/ha N, 132 kg/ha P and 112 kg/ha K. Hence, good soil fertility and adequate fertilization is needed to improve the yield of cassava. In spite of all the reports on cassava responsiveness to fertilization, farmers in Ghana hardly apply fertilizers to the crop as farmers are unsure about the root quality when fertilized. A survey carried out by Tettey and Frimpong (1991) came out with some perceptions of Ghanaian farmers on why fertilizers are not used on cassava as; the root of cassava rot when fertilized and reduction in the food quality of cassava root when fertilized.

Adoa (2009) reported, no negative effects in root cooking quality and mealiness when cassava was fertilized and recommended that, farmers should use fertilizers to increase the root yield of cassava.

He reported that, application of soil amendments improves the cassava root dry matter which, resulted increasing the cooking quality of cassava roots. A similar work was done by Safo-Kantanka and Owusu-Nipa (1992) and they reported a positive correlation between dry matter content and cooking quality of cassava roots. This was supported by a later findings by Safo-Kantanka and Asare (1993).

Other studies involving fertilization of cassava had shown that, fertilizing cassava improves the poundability of roots and to a larger extent improves the mealiness of varieties developed for cassava flour production (Adjei-Nsiah and Issaka, 2013).

According to Agbaje and Akinlosotu (2004), issues of root rot of cassava is mainly due to varietal differences but not fertilizer rates. This suggests that fertilization might not lead to root rot of cassava when harvested.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research work was carried out at the research field of the Crops Research Institute (CRI) at Fumesua-Kumasi from May, 2014 to May, 2015. Fumesua is located within latitude 6º, 41 North and 1º, 28 West. The area has bimodal rainfall pattern with the major season rains around April to June and minor season rains from August to November with annual rainfall of 1,345mm per annum. The temperature is usually high throughout the year with annual mean temperature between 22ºC to 31ºC. The vegetation is that of humid forest type. According to Adu and Asiamah (1992) the soil is that Ferric Acrisol Asuansi Series type.

3.2 Experimental design and Treatments

The experimental design was a 4 x 3 factorial experiment. The two factors studied were Rate of fertilizer (NPK 15 – 15 – 15) application and levels employed were 0, 200, 400 and 800kg/ha. The second factor was Time of fertilizer application which were 8, 16 and 24 weeks after planting (WAP). Treatments were arranged in the Randomised Complete Block (RCBD) design with 3 replications. Each replication had 12 plots which were separated from one another by a distance of 2m.

3.3 Variety Planted

The Cassava Variety 'Ampong' was used for the experiment. It is a new and early maturing variety released by the Crops Research Institute, Fumesua-Kumasi and can be harvested within 12 months.

The root become fibrous and rotten when harvesting is done beyond 15 months.

‘Ampong’ is a variety that branches earlier (about 1m above ground) and grows vigorously. It is poundable and also has starch content ranging between 22 – 27%. It has a potential yield between 20 – 50t/ha but yield depend mainly on environmental factors such as soil nutrients, management, moisture, duration and weed control. It has low dry matter content due to its high water content of about 60% however, this is compensated for by its high yields. ‘Ampong’ is tolerant to the African Cassava Mosaic Virus (ACMV) and its HCN content is below the injurious level of about 1mg/kg of root which makes it safe for consumption.

3.4 Cultural/Management Practices

3.4.1 Land Preparation

The field was slashed, ploughed and harrowed. It was then pegged out into replications and plots.

3.4.2 Planting

Cassava cuttings were cut at 25cm long with at least 5 nodes and planted at a space of 1m x 1m making a total plant population of 10,000 plants/ha. Each plot had 4 rows with a total of 20 plants/ sub-plot.

The stakes were planted at 45^o with 2/3 buried in the soil on 30th May, 2014. Refilling was done two weeks after planting to maintain the plant population.

3.4.3 Fertilizer Application

Fertilizer were applied to the plants on 24th July, 2014 (8WAP), 19th September, 2014 (16 WAP) and on 14th November, 2014 (24 WAP) according to the treatments. The fertilizer treatments applied were 0kg, 200kg, 400kg and 800kg NPK/ha and each plot/plant receiving 0g/plant, 20g/plant, 40g/plant and 80g/plant respectively. All the fertilizer treatments were applied to the plants in a half moon shaped furrow of about

3-5cm deep and 20cm from the base of the plant and covered.

3.4.4 Weed Control

Four weedings were done to control the weeds infestation. Weeding was done manually with hoe at 6 weeks intervals. Weedicide was, however, applied to control weeds around the plot after the close of the canopies.

3.5 Soil Analysis

3.5.1 Soil Sampling and Analysis

Soil samples were taken randomly at a depth of 0 – 15cm at three different spots across each of the replications before planting. The representative soil samples were bulked together and taken to the laboratory for analysis. The bulked samples were air dried and sieved through a mesh of 2mm. The analysis carried out include Soil pH, Organic Carbon, Total Nitrogen, Exchangeable Potassium and Available Phosphorus.

Soil pH was determined by using glass electrode pH meter in soil water suspension of a ratio 1: 2.5 (Rhodes, 1982).

Total Nitrogen: The micro Kjeldahl method was used. Ten grams of the soil sample was digested with concentrated sulphuric acid with Selenium as a catalyst making 100mls. Ten mils of aliquot was then steam distilled with addition of 40% NaOH. This was then collected in boric acid. The mixture collected was titrated with 0.1 M concentrated HCl. The percentage Nitrogen was then calculated.

Organic Carbon was measured with the Walkley and Black (1934) procedure. The carbon in the soil was oxidized with 1.0 M potassium dichromate, an acidified. 1.0M of ferrous sulphate was then titrated with unreduced dichromate. The percentage organic carbon was then multiplied by Van Bemmelen conventional factor of 1.724.

Available Phosphorus was measured using the Bray – 1 solution (Anderson and Ingram, 1989). During the extraction, Molybdenum and reducing agent was mixed and produced a blue colour phosphor-molybdonate. The available P was then measured with spectronic 20 at a wavelength of 520nm.

Exchangeable Potassium was measured by using ammonium acetate to extract the soil and potassium measured with flame photometer.

3.6 Growth Data Collected

3.6.1 Plant Height

Plant height was taken at 60, 120 and 180 days after planting (DAP). Four (4) plants from the two middle rows of each sub-plot were selected randomly. Measurements were taken from the base of the plant (soil level) to the tip of the terminal bud of each plant with graduated pole.

3.6.2 Height at First Branching

Height at first branching was taken from the four plants from the two middle rows of each sub-plot randomly selected. Measurements were taken from the base of the plant to the point of the first branch on each plant with a steel measuring tape.

3.6.3 Canopy Development / Spread

Canopy development/spread was measured twice at 120 and at 180 days after planting (DAP). A two wooden poles were placed opposite to each other at the tip of the canopy/leaf stretch. A steel tape was used to measure the interval between the two poles and the direction of measurement used was repeated for all the other plots.

3.7 Yield Data Collected

3.7.1 Number of Roots per plant

Four randomly selected plants from the two middle rows were harvested from each plot. The number of roots per plant were determined with a relation;

$$\text{No. of root/plant} = \frac{\text{Number of root harvested}}{\text{Number of plant harvested}}$$

3.7.2 Root Diameter

The diameter of roots from four randomly harvested plants from each plot were measured using the venier calipers.

3.7.3 Mean Weight per Roots

The mean weight/root was determined on harvested roots from randomly selected four plants from the two middle rows in each plot with the relation;

$$\text{Mean Weight/Plant} = \frac{\text{Weight of root harvested}}{\text{Number of roots harvested}}$$

3.7.4 Fresh Root Yield (t/ha)

An area covering $4m^2$ were harvested per treatment and the fresh root weight measured. It was then converted to kilogram (kg) per hectare and in tonnes per hectare as

$$\text{Fresh root yield (t/ha)} = \frac{10000m^2 \text{ x Weight of root harvested in kg}}{\text{Area harvested in } m^2}$$

3.8 Root Quality Factor Collected

3.8.1 Time to Cook

A root each from the test treatments and control were peeled, sliced and washed with distilled water. The sliced roots were then boiled with 500mls of distilled water. A fork was then used to check the roots when well-cooked and the time noted.

3.8.2 Hardness/ Softness after Cooking and Taste of Roots

A 10 member panel was constituted for the sensory test. All procedures were explained to the panelist before the exercise. Each of the panelist was given all the samples. Sample from the control was used as a reference for the comparison with that of the test treatment.

Samples from the test treatments were labelled A_1, A_2, A_3, B_1, B_2, B_3 and C_1, C_2, C_3 and that of control as D. A scoring sheet was given to all the panelist to score the taste and hardness/softness of the roots after cooking of the test treatment and the control. A bottle of water was given to the panelist to rinse their mouth after tasting each sample. A hedonic scale of 0 – 4 was used for the scoring as 0 = much worse, 1= slightly worse, 2 = same, 3 = better, 4 = much better and that of hardness/softness after cooking as 0 = very soft, 1= slightly soft, 2 = no difference, 3 = slightly hard, 4 = very hard.

3.8.3 Poundability and Quality after pounding

Poundability was assessed with a panel by making a piece of each sample into ball (sticky paste) by pressing it between the thumb and the index finger and samples were recorded as 0 = Not poundable, 1 = Slightly poundable, 2 = Poundable, 3 = Easily poundable (Raji *et al.,* 2007). The test samples and the control were subjected to pounding with a mortar and pestle. All the samples were then moulded into ball of 'fufu' and kept in a separate rubber bowls, observations made after 45 minutes after pounding. Assessment score recorded as 0 = very soft, 1 = Soft, 2 = no change, 3 = Hard, 4 = Very hard. In all, the control sample was used as a reference.

3.8.4 Scoring for Post-harvest Physiological Deterioration (PPD)

Twenty one roots each from the test treatments and the control were kept at ambient temperature for a maximum of 7 days. The process involved the use of the entire root as described by Morante *et al.* (2010) and cutting seven 2 cm thick in transverse slice along the root, starting from the proximal end (Wheatley *et al.,* 1985).

A scoring scheme ranging from 1-10 was assigned to each slice, corresponding to the percentage of the cut surface showing discoloration (1=10%, 2=20%, etc.). The mean post-harvest physiological deterioration scored for each root and was calculated by averaging the score for the seven transversal sections.

3.9 Determination of Dry Matter Content (DMC)

The roots from all the test treatments and the control were washed and grated into chips using a mechanical cassava grater. One hundred grams of the chips were sampled in two replicates. They were oven dried at 72° C for 72 hours, weighed and dry matter content determined by the relation;

$$DMC = \frac{\text{Dry Weight}}{\text{Wet Weight}} \times 100$$

3.10 Profitability analysis

The yield from the treatment plots and control plots were used for the assessment as per other cost involved in the treatment plots. These were then converted into cash as per market price for a kilogram of cassava.

3.11 Data Analysis

Data were analyzed with Genstat Statistical Package (Version 12), using analysis of variance (ANOVA). Treatments means compared with the Least Significant Differences method at 5% probability. The sensory evaluation data were analyzed with SPSS statistical software.

CHAPTER FOUR

4.0 RESULTS

4.1 Rainfall Data

The rainfall data for the study period is presented in Table 4.1. The lowest amount of rainfall 0.4mm was recorded in the month of January, 2015 and the highest 314.26mm recorded in the month of June, 2014. The total amount of rainfall for the study period was 1406.38mm which is inadequate to meet the total rainfall requirement for optimum growth of cassava.

Table 4.1 Rainfall for June, 2014 – May, 2015.

Yr.	**Rainfall in Month (mm)**												**Total**
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	
2014	-	-	-	-	-	314.3	83.8	74.6	107.8	139.1	110.8	1.2	831.5
2015	0.4	98.0	138.0	183.6	154.8	-	-	-	-	-	-	-	574.9

4.2 Soil Physical and Chemical Properties

The results of the physical and chemical properties of the soil sample at 0 – 15 cm are shown in Table 4.2. The total organic carbon was found to be 2.27%, the total nitrogen as 0.12%, the exchangeable potassium was found to be 0.38cmol/kg and that of available phosphorus as 4.96mg/kg. The pH of the soil was 6.8 and the soil texture was sandy loam and all the values were inadequate to provide the nutritional need of cassava.

Table 4.2. Soil Physical and Chemical Properties (0 – 15cm)

Soil Properties	0 – 15cm
Organic Carbon (%)	2.27
Total Nitrogen (%)	0.12
Potassium(Cmol/kg)	0.38
Available Phosphorus (mg/kg)	4.96
pH (y;H_2O)	6.8
Soil Texture	**Sandy loam**

4. 3. Canopy spread and height at first branching.

The results of canopy spread and height at first branching are shown in Table 4.3. Rate of fertilizer application significantly ($P< 0.05$) affected canopy at both sampling occasions. At 120 DAP, the greatest canopy spread was observed in the 400kg treatment and this was significantly higher ($P<0.05$) than those of the 200kg fertilizer and control treatments only. All other treatment differences were not significant. At 180 DAP, canopy spread from the 400kg fertilizer treatment was the greatest, which was significantly higher than the 200kg and control treatment only. All other treatment differences were not significant.

Time of fertilizer application did not significantly ($P>0.05$) affect canopy spread on both sampling occasions. Plant height at first branching was not significantly ($P>0.05$) affected by both rate and time of fertilizer application (Table 4.3).

Table 4. 3. Effect of Rate and Time of NPK 15 – 15 – 15 fertilizer on Canopy spread and height at first branching of cassava plant.

Treatment	Canopy Spread (cm)		Height at First Branching(cm)
	120 DAP	180 DAP	
Fertilizer Rates (kg NPK/ha.)			
Control	113.8	152.1	54.3
200	112.7	183.6	58.0
400	136.3	209.2	55.0
800	125.1	190.3	53.3
LSD (0.05)	21.5	28.1	NS
Time of Application (WAP)			
8	127.5	186.3	54.2
16	120.7	193.3	57.8
24	117.8	171.7	53.5
LSD (0.05)	NS	NS	NS
CV (%)	18.0	15.7	13.3

4. 4. Plant height

The results of plant height as affected by rates and time of fertilizer application are presented in Table 4.4. Rate of fertilizer application significantly ($P<0.05$) affected plant height at 120 and 180 DAP sampling only. On both days, treatment effect of the 400kg/ha fertilizer was the greatest, but this was significantly higher ($P<0.05$) than that of 200kg/ha fertilizer at 120 DAP, and the control treatment at 180 DAP. All other treatment differences were not significant on both days. Time of fertilizer application did not have any significant influence on plant height on all sampling days.

Table. 4.4. Effect of Rate and Time of NPK 15 – 15 – 15 fertilizer on plant height of cassava at 3 sampling periods.

Treatment	**Plant Height (cm)**		
	60 DAP	**120 DAP**	**180 DAP**
Fertilizer Rates (kg NPK/ha.)			
Control	15.57	83.2	152
200	12.90	80.2	183.6
400	16.70	101.7	209.2
800	15.28	86.0	190.3
LSD (0.05)	NS	19.5	28.1
Time of Application (WAP)			
8	13.93	92.4	186.3
16	15.79	87.2	193.3
24	15.64	83.8	171.7
LSD (0.05)	NS	NS	NS
CV (%)	30.8	22.8	15.7

4.5 Number of roots and root diameter

The result of number of roots/plant and root diameter as influenced by rate and time of fertilizer application are presented in Table 4.5. Rate of fertilizer application significantly (P<0.05) affect number of roots per plant and the highest number of roots was observed among the 400kg treatment which was significantly higher (P<0.05) than that of control treatment only. The rest of the treatment differences were not significant (P>0.05).

Time of application did not significantly (P>0.05) affect number of roots per plant. Both rate and time of fertilizer application did not significantly (P>0.05) affect root diameter (Table 4.5).

Table 4.5 Effect of Rate and Time of NPK 15 – 15 – 15 fertilizer on number of roots and root diameter of cassava.

Treatment	Number of Root/ plant	Root Diameter (mm)
<u>**Fertilizer Rates (Kg NPK/ha)**</u>		
Control	4.33	47.5
200	6.03	46.9
400	6.50	52.5
800	5.44	51.9
LSD (0.05)	1.5	NS
<u>**Time of Application (WAP)**</u>		
8	. 5.82	49.7
16	5.13	49.9
24	5.93	49.5
LSD (0.05)	NS	NS
CV (%)	28.3	12.9

4.6 Mean root weight and yield

Results of mean root weight and fresh root yield as affected by rate and time of fertilizer application are shown in Table 4.6. Rate of fertilizer application significantly (P<0.05) affected mean root weight. The greatest mean weight was recorded in the 800kg treatments and was significantly (P<0.05) higher than the control treatment effect only.

There were significant ($P<0.05$) differences among the treatments on fresh root yield. The greatest yield was measured in the 800kg treatment, which was significantly higher than only the control treatment effect. All other treatment differences were not significant.

Time of fertilizer application did not significantly ($P>0.05$) affect both mean root weight and fresh root yield (Table 4.6).

Table 4.6 Effects of Rate and Time of NPK 15 – 15 – 15 fertilizer application on mean root weight and fresh root yield of cassava.

Treatment	Mean root weight (Kg)	Fresh root yield (t/ha)
Fertilizer Rates (Kg NPK/ha)		
Control	0.35	23.0
200	0.41	26.2
400	0.55	36.0
800	0.56	30.8
LSD (0.05)	0.1	10.1
Time of Application (WAP)		
8	0.45	27.3
16	0.45	29.3
24	0.50	31.9
LSD (0.05)	NS	NS
CV (%)	34.5	36.0

4.7 Post-harvest Physiological Deterioration and Dry Matter Content

The rate and time of fertilizer application on post-harvest physiological deterioration (PPD) was not significant (P>0.05) in all the three sampling periods Table 4.7.

Dry matter content was affected by amount of fertilizer applied as the difference between the 200kg treatment, which was the greatest and that of 800kg treatment, the lowest, was significant (P<0.05). Time of fertilizer application did not affect dry matter content.

Table 4.7 Effect of Rate and Time of NPK 15 – 15 – 15 fertilizer application on Post-harvest Physiological Deterioration and Dry Matter Content of cassava.

Treatment	Post-harvest Physiological Deterioration (%)			
	3 DAH	5 DAH	7 DAH	Dry Matter Content (%)
Fertilizer Rates (Kg NPK/ha)				
Control	1.36	2.01	1.94	31.87
200	1.51	2.18	1.94	33.37
400	1.45	1.92	2.05	32.70
800	1.55	1.86	1.73	30.02
LSD (0.05)	NS	NS	NS	2.9
Time of Application (WAP)				
8	1.42	1.76	1.95	30.59
16	1.55	2.37	1.99	33.16
24	1.44	1.85	1.80	32.22
LSD (0.05)	NS	NS	NS	NS
CV (%)	38.6	33.2	28.0	9.4

4.8 Sensory evaluation of cassava roots as influenced by rate and time of fertilizer application

Table 4.8 present the results of the sensory evaluation. It shows that, time of cooking were similar to that of the control in all the treatment. Taste of roots in the 200Kg, 400kg and 800kg treatment were similar to the control at 8 WAP, 200kg at 24 WAP, 400kg at 16 WAP and 800kg at 16 and 24 WAP. Softness/hardness after cooking were rated similar to the control at 200kg, 400kg and 800kg treatment at 24, 8 and 24 WAP respectively but the rest scored differently to the control. The roots were rated as poundable in all the treatment to the control and scored to be the same as the control in terms of quality after pounding but were recorded soft at 800kg treatment at 8 and 16 WAP only.

Table 4.8 Sensory evaluation of cassava roots as influenced by rate and time of fertilizer application

Treatment	200Kg			400Kg			800Kg		
Quality factor	8 WAP	16 WAP	24 WAP	8 WAP	16 WAP	24 WAP	8 WAP	16 WAP	24 WAP
Time to cook (in minutes)	20:01	20:10	21:10	19:15	22:00	20:17	18:25	20:02	19:20
Taste	2.3	1.9	2.4	2.9	2.0	1.8	2.2	2.4	2.8
Softness/ Hardness	1.7	1.6	2.0	2.7	1.8	1.7	1.8	1.9	2.2
Poundability	2.0	2.2	2.0	1.9	2.1	1.8	2.3	2.3	2.0
Quality after pounding	2.2	2.3	2.4	2.1	2.1	2.1	1.9	1.9	2.1

Means for 10 respondents.

Scoring: Taste – 0 = much worse, 1 = slightly worse, 2 = same, 3 = better, 4 = much better

Softness/hardness after cooking – 0 = very soft, 1 = slightly soft, 2 = no difference, 3 = slightly hard, 4 = very hard

Poundability – 0 = not poundable, 1 = slightly poundable, 2 = poundable, 3 = easily poundable

Quality after pounding – 0 = very soft, 1 = soft, 2 = no change, 3 = hard, 4 = very hard

4.9 Economic analysis of the NPK fertilizer use

The result of the economic analysis for the various treatments (Table 4.9) shows that 400kg fertilizer treatment gave the highest extra gain in net benefit of GH₵ 6719.00, GH₵ 4707.00 and GH₵ 8792.00 when applied at 8 WAP, 16 WAP and 24 WAP. The 200kg treatment recorded negative extra gain in net benefit of GH₵ -1998.00 and GH₵ - 154.00 when applied at 16 WAP and 24 WAP respectively.

The highest profit of GH₵ 8792.00 was recorded by the application of 400kg fertilizer treatment at 24 WAP and the 800kg fertilizer treatment given its highest profit of GH₵ 6524.00 at 24 WAP.

Table 4.9 Economic Analysis for the different fertilizer treatment rates and time of application

Time of Appl.	8 WAP				16 WAP				24 WAP			
Fert. Rates	Control	200kg/ha	400kg/ha	800kg/ha	Control	200kg/ha	400kg/ha	800kg/ha	Control	200kg/ha	400kg/ha	800kg/ha
Average yield (t/ha)	20.2	31.3	33.1	24.8	26.3	24.0	35.9	30.9	22.5	23.3	38.9	36.7
Adjusted yield (t/ha)	18.2	28.2	29.8	22.3	23.7	21.6	32.3	27.8	20.3	21.0	35.0	33.0
Gross benefit (GH₵/ha)	12194.00	18894.00	19966.00	14941.00	15879.00	14472.00	21641.00	18626.00	13601.00	14040.00	23450.00	22110.00
Total variable cost (GH₵/ha)	1225.00	1814.00	2278.00	3206.00	1225.00	1816.00	2280.00	3208.00	1225.00	1818.00	2282.00	3210.00
Net benefit (GH₵/ha)	10969.00	17080.00	17688.00	11735.00	14654.00	12656.00	19361.00	15418.00	12376.00	12222.00	21168.00	18900.00
Extra benefit	-	6111.00	6719.00	765.00	-	-1998.00	4707.00	764.00	-	-154.00	8792.00	6524.00
Marginal analysis	-	10.38	6.38	0.39	-	-3.38	4.46	0.39	-	-0.26	8.32	3.29
Percentage	-	1038%	638%	39%	-	-338%	446%	39%	-	-26%	832%	329%

CHAPTER FIVE

5.0 DISCUSSION

5.1 Vegetative growth of cassava as influenced by rate and time of fertilizer application

From the results, the rate of fertilizer application did not significantly affect plant height at 60 DAP, however significant differences were observed among 400kg and 800kg treatment at 120 DAP and 180 DAP. The 400kg treatment recorded the greatest height of 209.2cm at 180 DAP. These observations support the report of Krochmal and Samuels (1970) that, application of high level of N will lead to 11% increase in top growth. A report by Hershey (2005) showed that a matured cassava plant can reach a height between 1 – 2m high. Time of fertilizer application did not affect plant height implying that farmers can apply NPK to cassava at any time and this will not affect plant height of plant. Howeler (1990) also reported no significant differences between single application at 30 DAP and split application at 30 and 60 DAP or at 30, 60 and 90 DAP.

Canopy development was also affected by the various treatment in the two sampling periods (Table 4.3). The 400kg treatment recorded significant ($P<0.05$) effect to the 200kg and the control treatment at 120 DAP and at 180 DAP. This confirm the findings of Sanchez (1976) and Onwueme and Charles (1994) who reported that excess amount of K and N leads to luxuriant growth at the expense of root formation. Time of application did not produce any significant differences in the spread of the canopy. This again conformed to earlier reports by CIAT (1982) and Howeler (1990) that no significant differences exist between single applications at 30 DAP and split application of fertilizers at 30 and 60 DAP or at 30, 60 and 90 DAP.

5.2. Cassava root yields and its components

Number of roots/plant were significantly affected by rate of fertilizer application with root yield of the 400kg being greater than the 200kg and the control treatments. Perhaps, the observed reduction in root yield following the application of 800kg/ha NPK relative to the 400kg/ha NPK could be due to steady increase in soil pH resulting from the excessive amount of N supplied (Line-Kelly, 2004). Issaka *et al.,* (2007) reported that increase in nutrient levels results in increase in number of roots formed and contrary to Agbaje and Akinlosotu (2004) who reported that number of roots per plant were not influenced by fertilizer application.

The result obtained with respect to fresh root yield indicated that fresh root yield was significantly ($P<0.05$) affected by rate of fertilizer application. The greatest fresh root yield 36.0t/ha was recorded for 400kg treatment with the control treatment recording the least fresh root yield of 23.0t/ha as more P and K necessary for root formation and inducing net photosynthetic ability of a leaf area which helps in translocation of photosynthate to the roots respectively were made available to the plant. The high yield of 400kg treatment could be a factor of higher light interception due to its higher canopy spread as reported by Lahai (2011). The results support the findings of FAO (1999) that fertilization can increase crop yield up to 49% in West Africa and Paula *et al.* (1983) reported that, cassava yield can be increased by 30% when fertilized. A report by Vanlauwe (2012) who indicated that yield of cassava increased from 12 to 25t/ha when moderate level of NPK was applied and when higher rates were applied yield increase more than 40t/ha. The results also confirms earlier report by Agbaje and Akinlosotu (2004) that yield of cassava dropped when fertilized with 400kg and 800kg NPK/ha.

However, all the yield figures recorded fell within the achievable yield range 20 – 50t/ha for the Ampong variety (Manu-Aduening, personal communication).

The amount and distribution of rainfall 1406.38mm and edaphic conditions during growth period of the crop may have resulted into the inability of the crop to attain its highest yield as reported by Duque *et al.* (2008) that, water stress during the early growth (1-5 months) has severe implications for root yield as this is the period for storage root initiation and Anneke *et al.* (2009) also reported that, cassava responsiveness to fertilization reduces if total rainfall is below 1500mm.

5.3 Dry matter content, postharvest physiological deterioration (PPD)/storage time and root quality factors

The dry matter yield obtained in this studies were relatively low which were significant, contrary to a report by Adjei-Nsiah and Issaka (2013) that, fertilization did not significantly result in an increased percentage dry matter yield. The low dry matter content is characteristics of the Ampong variety because of the high water content of about 60% (Personal communication – Manu-Aduening). The high water content possibly led to the dilution of the assimilates stored in the roots.

No significant differences were observed in the PPD of all treatments after 7 days after harvesting. The findings contradict earlier report by Ekanayake and Lyass (2003) who stated significant differences in the development and PPD severity in cassava varieties. The findings also confirm report made by Jennings and Iglesias (2002) who found strong correlation between PPD and dry matter content, which means that when dry matter is low PPD will also be low and vice versa. The low PPD level could also be attributed to the method employed in the studies which involved the use of the entire roots (Morante, 2010) without cutting the proximal and the distal ends described by Wheatley *et al.* (1985) which accelerate PPD.

Breeding programmes could also be the results of the low PPD as more work is being geared towards reducing high rates of PPD among cassava varieties which make the root unacceptable by consumers.

It also reject the perception of Ghanaian farmers that fertilizer application leads to rotting of cassava roots after harvesting as reported by Tettey and Frimpong (1991). Agbaje and Akinlosotu (2004) reported that incidence of rot is not a factor of fertilizer application rather varietal differences.

The results of the root quality factors in Table 4.8 shows that time of cooking of all the treatment were similar to the control treatment. The taste of the roots did not also vary significantly. The results is contrary to the perception of Ghanaian farmers that fertilizer application reduces the tastes of cassava roots (Tettey and Frimpong, 1991).

All the treatments recorded poundability similar to the control. This confirms earlier reports made by several researchers including Adoa (2009) who reported no negative effect in root cooking quality and mealiness when cassava was fertilized.

Rather, he reported that application of soil amendments improves the root dry matter which improve the cooking quality of cassava roots. A similar observation was made by Adjei-Nsiah and Issaka (2013) who reported that fertilizer application improved the poundability of cassava roots and to a larger extent improved the mealiness of variety developed for cassava flour production. The quality of roots after pounding was observed 45minutes after pounding and all the treatments recorded similar effects as the control treatment.

5.4 Economic analysis of cassava fertilization

Based on a partial budget used for the economic analysis all the yield obtained were reduced by 10% as suggested by CIMMYT (1988) and the adjustable yield was then used for the analysis as per cost of production (variable cost). The result revealed that, with the exception of the 200kg/ha treatment at 16 and 24 WAP all the other treatment recorded profitable indicating that any extra cost spend on fertilizer will lead to extra benefit. The most economical and profitable treatment for all the treatment was the 400kg treatment, as it recorded the greatest extra benefit of GH₵
8792.00 at 24 WAP which confirm what was reported by Adjei-Nsiah and SakyiDanso (2012) that fertilization results in higher revenue (extra benefit).

The 200kg treatment gave the highest benefit GH₵ 6111.00 when applied at 8 WAP. The 800kg treatment also recorded GH₵ 6524.00 as its greatest extra net benefit. In addition, the nonprofitable among the treatments was the 200kg/ha treatment which recorded negative extra net benefit of GH₵ -1998.00 and GH₵ -154.00 when applied at 16 WAP and 24 WAP respectively. This findings also indicate that when fertilizer is applied at the required quantities and time, it will lead to higher profit gain by farmers as suggested by Anneke *et al.* (2009) that, smallholder farmers in Africa should use fertilizers to increase cassava productivity and profitability.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The following conclusions could be made from the results obtained. Cassava responded positively to fertilizer application as well as in most growth and yield factors, the fertilized treatments were better than the control treatments. The 400kg treatment was the optimum rate of the fertilizer and can be applied at any time for the variety used. Additionally, fertilizer application did not affect cooking and pounding qualities of cassava roots, as well as the roots shelf life. However, time of fertilizer application did not affect the growth, yield and quality factors evaluated. The most profitable rate of fertilizer application was the 400kg/ha and that farmers should use fertilizers to increase yield and income.

6.2 Recommendation

It is recommended that, since rainfall was below optimum, the research can be repeated to verify where same results would be obtained under normal conditions. Further research on time of fertilizer application can be carried out to give farmers assurance that within certain time limits, fertilizer can still be applied to obtain results.

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