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GROWTH, YIELD AND ROOT QUALITY OF CASSAVA AS AFFECTED BY APPLICATION OF ORGANIC AND INORGANIC FERTILIZERS

BY

HAYFORD SARFO

SEPTEMBER, 2015.

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES, COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST), KUMASI, GHANA, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPY DEGREE

Mphil. AGRONOMY DEGREE

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DECLARATION

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

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ABSTRACT

A study on growth, yield and root quality of cassava as affected by the application of organic and inorganic fertilizers was carried out at the research field of CSIR-Crops Research Institute at Fumesua in the Ashanti Region of Ghana. The experiment was 3x4 factorial with the treatments arranged in a randomized complete block design with three replications. Fertilizer types were: N-P_2O_4-K_2O at a rate of 30-60-60kg/ha, Poultry Manure (PM) at a rate of 4t/ha, NPK x PM and no treatment as Control. The varieties were: *Sika*, *Ampong* and *Bankyehemaa.*

The response variable were: plant height, height at first branching, canopy spread, shoot biomass (t/ha), number of roots per plant, roots diameter, mean root weight (kg/ha), root yield (t/ha), harvest index, root dry matter content, starch content and cooking quality. Planting materials were obtained from Crops Research Institute. Setts were cut to about 15 cm and planted at 1x1 m at the beginning or rains.

Results showed that all varieties responded to application of both organic and inorganic fertilizer. In all parameters, the fertilizer treatment effects were greater than the control treatment. Application of the poultry manure only resulted in the greatest root diameter and number of roots per plant. However, the combined application of organic and inorganic fertilizers produced the greatest root weight and root yield. Fertilizer treatments did not adversely affect root quality but enhanced the cooking qualities of the cassava varieties. The results show that for farmers to obtain greater yields than what they are currently harvesting, fertilizer application in cassava production must be employed especially on low nutrient soils.

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DEDICATION

To my baby boy Nana Sarfo K. Hayford.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF ABBREVIATIONS

A.D	*Anno Domini*
AGDP	Agricultural Gross Domestic Product
CBSD	Cassava Black Streak Disease
CIAT	International Center for Tropical Agriculture
CMD	Cassava Mosaic Disease
CRI	Crops Research Institute

CSIR	Council for Scientific and Industrial Research
CTA	Technical Centre for Agricultural and Rural Co-operation
ESCaPP	Ecologically Sustainable Cassava Plant Protection project
FAO	Food and Agriculture Organization of United Nations
FOASTAT	Food and Agriculture Organization of United Nations, Statistics Database
HCN	Hydrogen Cyanide
IFAD	International Fund for Agriculture Development
IITA	International Institute of Tropical Agriculture
MOFA	Ministry of Food and Agriculture
MTADP	Medium-Term Agricultural Development Project
NARP	National Agricultural Research Project
NRCRI	National Root Crops Research Institute
NTRCIP	National Root and Tuber Crops Improvement Project
PM	Poultry Manure
UNESCO	United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

1.1 Introduction

Cassava (*Manihot esculenta Crantz*) is a perennial shrub of the family *Euphorbiaceae* cultivated mainly for its starchy roots. On a worldwide basis it is ranked as the sixth most important source of calories in the human diet (FAO, 2006). World production of cassava root was estimated to be 184 million tons in 2002, and rose to 230 million tons in 2008 (FAOSTAT, 2011). Worldwide cassava production increased by 12.5% between 1988 and 1990, with Nigeria as the world's largest producer of cassava (Parkes *et al.*, 2012).

Cassava is one of the important crops in tropical regions of the world (Scott *et al.*, 2000). It is a major staple food crop of the people in most parts of Africa, plays an important role in terms of food security, employment and income generation for farm families in parts of the humid tropics. It also derives its importance from the fact that it produces more calories/unit area from its starchy tuberous root which is a valuable source of cheap calories especially in developing countries (Dixon, 2002). It is an important industrial raw material for the production of starch, alcohol, pharmaceuticals, gums, confectioneries and livestock feed (Nnodu *et al.*, 2006). In many parts of Africa, the leaves and tender shoots are also consumed as vegetables (Eke-Okoro and Dixon, 2000). Ethanol from cassava is used as biofuel in most of the developed world because it causes no air pollution or environmental hazard.

In Ghana, cassava occupies an important position in the agricultural economy and contributes about 46% of the agricultural gross domestic product (Parkes *et al.,* 2012). They further observed that cassava accounts for a daily caloric intake of 30% in Ghana and is grown by most farm families. Yields of over 30t/ha is achievable in Ghana if recommended technologies for the crop is fully adopted and practiced (MOFA, 2003).

The crop is grown extensively in almost every part of the country, because it has earned the reputation of being well adapted to soils of low fertility and low rainfall (Stone, 2002). This stems from its ability to produce some yield, (5-6 t/ha), in subsistence agricultural systems on soils of low fertility status and has contributed greatly to its success over other staple food crops (IITA, 1990). The crop has an extensive root system that is able to utilize plant nutrients less accessible to other crops.

Farmers are therefore motivated by this inherent genetic ability of the crop, and do not apply fertilizer in cassava farms as they are contented with the minimal yield obtained from using limited inputs from their poor soils, among other reasons such as the cost of the fertilizers and their availability.

At present, cassava has assumed the status of an industrial crop in Ghana. It is now being grown on a relatively large scale, repeatedly season after season on the same piece of land (Asare *et al.*, 2009). Under this condition, the fertility of the soil and yields declined overtime (Nguyen *et al.*, 2001). Decline in soil fertility is especially serious in tropical regions where the soil lacks adequate plant nutrients and organic matter due to leaching and erosion of top soil by intense rainfall (Ayoola and Makinde, 2007). Cassava extracts substantial amounts of nutrients with the harvested roots, the highest being K, followed by N, Ca, Mg and P; and if not adequately fertilized, will exhaust soil nutrients under continuous cropping (Nguyen *et al.*, 2001). However, to produce high yields, the crop does require large supplies of nutrients and this requirement can be met through the use of fertilizers. The crop has been reported to respond to good soil fertility and adequate fertilizer application (Issaka *et al.*, 2007).

Research in Nigeria has shown that the crop yield can be increased and even maintained for many years with adequate fertilizers or manures (Parkes *et al.*, 2012). The major nutrients required by cassava for optimum growth and tuber yields are nitrogen (N) and potassium K (Howler, 1990). Adequate K levels in soil stimulate response to N fertilizers but excess amount of both nutrients leads to luxuriant growth at the expense of root formation (Onwueme and Charles 1994).

Ayoola and Makinde (2007) stated that the plant is well adapted to low levels of available P (on account of its mycorrhizal association which makes P available to it) but requires fairly high levels of N and K, especially when grown for many years on the same plot or continuously cultivated plots. Thus, sustainable continuous production of cassava on the same piece of land would require the application of supplementary nutrients.

The agricultural land to man ratio in developing countries keeps diminishing as a result of various activities such as urbanization, mining and road construction coupled with high population growth. There is, therefore, a lot of pressure on agricultural land and soil fertility in particular such that the old culture of shifting cultivation cannot be practiced in this era of high population growth. Most farmers have resorted to continuous cropping in Sub-Saharan Africa leading to nutrient mining and low yield. Parkes *et al.* (2012) noted that Ghanaian soils are inherently low in fertility and their restoration over the years after long periods of exhaustion is by bush fallowing for 10 or more years. With the rising growth in population and its associated pressure on land resources, cropping systems have become both permanent and continuous.

Cassava is the most widely cultivated crop in Ghana (FAO, 2006) and consumed in various forms by a large percentage of the populace. Its production has increased considerably in recent years, as a direct result of the importance of the crop as an industrial crop in natural starch manufacture, brewery and also as an export commodity. It is also due to its significance as a staple food crop that is eaten in various forms such as *fufu, ampesi, abetee, gari* and tapioca among others (AgyenimBoateng and Boadi, 2007). The average crop yield in Ghana is 12 t ha^{-1} against a recommended and achievable yield of 28 t ha^{-1} (MOFA, 2003).

To increase and maintain yield potential of cassava, the crop had been reported to respond to good soil fertility and adequate fertilizer application (Howler, 1996). However, farmers do not fertilize cassava because they are content with the minimal yields obtained from using limited inputs or even from their infertile soils. The indifference towards low productivity can be attributed to the low and unstable prices of cassava tubers (Agbaje and Akinlosotu, 2004). Fertilizer requirements for optimum yield in cassava are determined by factors such as, soil fertility status of the farmland, cropping system adopted and the rainfall pattern during the growing season.

Continuous cropping of cassava particularly the high yielding varieties without adequate maintenance of soil fertility could lead to soil and environmental degradation. As an efficient soil nutrients miner, cassava removes large quantities of N and K and also of P and Mg (Kang and Okeke, 1991). For instance, a harvest of 25 tons/ha of cassava removes about 60 kg/ha of N, 40 kg/ha of P_2O_5 and 136 kg/ha of K_2O (NARP Roots and Tubers Research Program, 1996). There is the need to upgrade the existing fertilizer recommendations to ensure sustained productivity, while ensuring minimum polluting effects on the environment (Parkes *et al.*, 2012).

Parkes *et al.* (2012) noted that, for most crops, the best fertilizer types, rates and time of application are not known and that this constitutes a major constraint to fertilizer use in the country. Even where available, these figures are old and new recommendations must be found and made available to farmers. There is the need to undertake a comprehensive research to assess the growth, yield and tuber quality of three cassava varieties following organic and inorganic fertilizer use.

1.2 Objectives of the Study

The main objective of the study was to assess the impact of fertilizer application on cassava production.

The specific objectives were:

i. To determine the effect of organic and inorganic fertilizer application on growth and yield of cassava ii. Identify appropriate fertilizer type, which will increase growth and yield of cassava. iii. To determine root quality as affected by fertilizer application.

iv. To determine the cost-benefit of the use of fertilizer in cassava production

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Origin, Spread and Production of Cassava

Cassava (*Manihot esculenta* Crantz) was domesticated sometime in the distant past by Amerindians of South America, however, exactly where is not known, but the current consensus is that domestication took place somewhere in Central or South America, perhaps along the southern border of Brazil, where wild relatives of cassava are currently found (Oslen and Schaal, 1999). According to Akinpelu *et al.* (2011), cassava has its origin in Latin America where it has been grown by the indigenous Indian population for at least 4000 years.

The crop was introduced from Brazil, its country of origin, to the tropical areas of Africa, the Far East and the Caribbean Islands by the Portuguese during the 16th and 17th centuries (Okogbenin *et al.*, 2006). Cassava plantations were set up by the Portuguese who colonized South American regions by 1500 A.D. They carried cassava from these plantations to other continents (Manu-Aduening *et al.*, 2005).

Cassava arrived in West Africa through the Gulf of Benin and then to East Africa in the 18th Century through the island of Reunion, Madagascar and Zanzibar (Oslen and Schaal, 1999). 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 name for cassava 'Bankye' could most probably be a contraction of 'AbanKye' - Gift from the Castle (Manu-Aduening *et al*., 2005).

MOFA (1997) stated that the spread of cassava from the coast into the hinterland was very slow. It reached Ashanti, 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 preferred in the north. Cassava became firmly established in most areas after the serious drought of 1982/83 when all other crops failed completely (Korang-Amoakoh *et al.,* 1987). Cassava and its various preparations including *fufu*, *gari* and *konkonte* are now very popular foods throughout Ghana (MOFA, 1997).

The world production of cassava root was estimated to be 184 million MT in 2002, rising to 230 million MT in 2008 (FAOSTAT, 2011). The majority of production was in Africa where 99.1 million MT were grown, 51.5 in Asia and 33.2 in Latin America and the Caribbean (FAO, 2005).

Nigeria is the world's largest producer of cassava with 45 million metric tons (FAO, 2008). However, Thailand is the largest exporting country of dried cassava with a total of 77% of world export in 2005, followed by Vietnam, with 13.6%, Indonesia 5.8% and Costa Rica 2.1% (FAOSTAT, 2010). Worldwide, cassava production increased by 12.5% between 1900 and 1988 (FAO, 2005). According to FAOSTAT (2010) the average yield of cassava crops worldwide, in 2010 was 12.5 tons per hectare. The most productive cassava farms in the world were in India, with a nationwide average yield of 34.8 tons per hectare in 2010.

2.2 Cassava Production and Research in Ghana

Cassava is a major crop in the farming systems of Ghana. It is a main source of carbohydrates to meet the dietary requirements and a regular source of income for most rural dwellers (FAO, 1994). The importance of cassava in Ghana can be seen in terms of crop area, total production, contribution to Agricultural Gross Domestic Product (AGDP) and food expenditure shares (Alderman and Higgens, 1992).

The average area planted to cassava which was about 387 000 ha in 1986 was projected to 590 000 ha in 1996 (Dapaah, 1996). During the same periods, cassava production also increased from about 2.9 million tons to 7.11 million tons. Cassava is so far the largest agricultural commodity produced in Ghana and represents 22 percent of AGDP compared to 5 percent for maize, 2 percent for rice, sorghum and millet, 14 percent for cocoa, 11 percent for forestry, 7 percent for fisheries and 5 percent for livestock (Dapaah, 1996).

Various research and efforts were made to develop cassava in the 1930s after it had been introduced into Ghana from Brazil in the 16th century; however, past government policies marginalized the crop in favour of export crops and maize (FAO, 1994).

Earlier research efforts focused attention on the selection of varieties for high yields, low HCN content and good cooking qualities and breeding for improved pest and disease resistance.

According to FAO and IFAD (2001), there was limited information on husbandry practices for the realization of high yields of selected varieties. However, effective measures were put in place to check the spread of diseases including the Cassava Mosaic Virus Disease, Cassava Bacterial Blight and pests such as cassava mealybug and cassava green spider mite. Since 1984, a biological control program has been established by MOFA for the control of major pests of cassava. The remarkable achievements of the biological control program being implemented by a multidisciplinary team is developing, testing and adapting sustainable cassava plant protection technologies in Ghana under the ESCaPP (Ecologically Sustainable Cassava Plant Protection project (FAO, 1994).

In 1988, the National Root and Tuber Crops Improvement Project (NTRCIP) was launched as a component of the IFAD sponsored Ghana Smallholder Rehabilitation and Development Program (SRDP) and in collaboration with IITA, three improved cassava varieties were released to farmers in 1993 (NARP, 1996). This effort is being complemented by the implementation of various activities on cassava under the National Agricultural Research Project (NARP) including; crop improvement, agronomy, integrated pest management, post-harvest management, processing and socio-economic studies by the research institutions and universities.

The launching of the Medium-Term Agricultural Development Project (MTADP) in 1991 by MOFA and government policies thereafter have contributed to the realization of the importance of cassava in Ghana. Some of the programs and projects being implemented under the MTADP provide modest support for research on the development of high yielding, pest and disease resistant varieties. After launching of the NARP, the production, processing and socio-economic aspects were investigated by relevant research institutions (NARP, 1996).

In the traditional bush-fallow system, some cassava plants are left to grow with the fallow which is long enough to enable the cassava to flower and set seed. This leads to the production of hybrid combinations from self-sown seed from which farmers select and propagate desirable types. Over 30 local varieties were identified in 1930, and by 1960 the number had increased to over 90 (Doku, 1996). Selections were made on account of the plant's excellent cooking qualities, low HCN content and high yields. These are used as parents in breeding programmes mainly to improve pest and disease resistance.

Between 1928 and 1962, the Department of Agriculture was responsible for cassava research and extension in Ghana. Since 1962, research institutions under the CSIR and the universities have been responsible for cassava research. Where systematic breeding and selection started in 1930 and is carried out mainly to improve pest and disease resistance and yields of the local varieties including; the Cassava Mosaic Virus Disease, Cassava Bacterial Blight, cassava mealybug and cassava green spider mite (FAO/IFAD, 2005).

Biological control of cassava pests and introduction of improved varieties from IITA was triggered by the drought of 1982/83 which heightened the impacts of the cassava pests and diseases. Government in collaboration with FAO and IITA, *mealybug* and green spider mite were controlled with the introduction of a parasitoid wasp (*Epidinocarsis lopezi*) and predatory insects (Diomus sp. and two Hyperdspisspp, Sympherobiussp, and mites, *Neoseiulusidaeus N. anonymus* were introduced (FAO/IFAD, 2005).

A number of fertilizer trials have been carried out mainly at the Soil and Crops Research Institutes and the Universities, but most of the results are yet to be developed into definite recommendations and made available to farmers **(**FAO, 1994; FAO and IFAD 2005). However, more work should be done on the effects of fertilizers in order to arrive at firm recommendations, especially for large-scale farms and recurrent climate change issues. Other research interventions included; The National Root and Tuber Crops Improvement Project (NRTCIP) in 1988 and National Agricultural Research Project (NARP) in 1991 which supported the National Agricultural Research Plan and other selected research programmes. The Root and Tuber Crops Research Programme of the NARP is being coordinated by the Crops Research Institute (CRI) and currently undertaking the following activities on cassava: Crop improvement, Agronomy, Integrated pest management, Product development and Socio-economic studies (FAO, 1994; NARP, 1996).

Collaborating institutions of the Root and Tuber Crops Research Programme of the NARP were: Crops Research Institute, Soil Research Institute, Savannah Agricultural Research Institute, Plant Genetic Resources Centre, Food Research Institute, Biotechnology and Nuclear Agricultural Research Institute, Kwame Nkrumah University of Science and Technology, University of Ghana, University of Cape Coast, University for Development Studies, (FAO & IFAD, 2005; NARP, 1996). The programme also collaborated with the International Institute of Tropical Agriculture (IITA), in the exchange of germplasm and training of research and technical staff. Cassava tubers are highly perishable and begin to deteriorate two to three days after harvesting. Post-harvest handling of the root crop is extremely important. Approximately, 30 percent of cassava produced is consumed by the producers, whilst the rest is sold on markets and a large proportion of this is processed into various indigenous products such as *gari*, *agbelima* and *kokonte* (FAO, 1994; Ofori *et al*., 2005).

The major intervention in cassava processing has been the introduction of a mediumscale motorized cassava grater by the Agricultural Engineers Limited in 1966. The cassava grater presented a great innovation in cassava processing since grating is central to traditional processing of cassava in Ghana (FAO and IFAD, 2005). Since then, several equipment manufacturers including engineering firms, research institutes, university departments, small-scale artisanal shops, blacksmiths and mechanics have developed and produced various types of cassava processing equipment (Ofori *et al.*, 2005).

2.3 Botany

Cassava (*Manihot esculenta*), is a perennial woody shrub in the Euphorbiaceae family which may grow to a height of 1m to 2.75 meters tall and some varieties reaching 4m. Branching height can be as low as 20 cm, while some cultivars never branch. Cassava leaves are deeply divided into 3–7 lobes (usually odd numbers) arranged spirally around the stem (Ekanayake *et al*., 1997). The leaves consist of petiole, of which are light greenish to red and blade which are attached or slightly (up to 2 mm) peltate, dark green above, pale light greenish grayish underneath, sometimes variegated.

It is monoecious, that is male and female flowers are found on the same plant. The inflorescence is formed from the terminal bud of the stem; sometimes, inflorescence can be formed in the leaf axil on the upper part of the plant. The female flower is on the lower part of the inflorescence and it normally opens 10-14 days before the male flower on the same branch; however, self-fertilization can occur as a result of male and female flowers on different branches or on different plant of the same genotype opening at the same time **(FAOSTAT, 2012).**

Cassava is basically cross-pollinated and highly heterozygous but vegetative propagation can result in a high degree of self-pollination in single cultivar. Pollen is generally yellow or orange, varying from 122-148 µm in size (Ghosh *et al*., 1988). The ovary is tricarpellary with 6 ridges and is mounted on the basal disk; with the 3 locules contain one ovule each. The fruit is a trilocular capsule which is ovoid or globular, each containing a single seed. It is small; roughly 1 cm in diameter and maturation generally occurs 3-5 months after pollination (Ghosh *et al*., 1988). When the fruit is dry, the endocarp splits explosively to release and disperse the seed (Rogers, 1965).

The shrub is often grown as an annual and propagated from stem cuttings after tubers have been harvested. The outer bark of the stem is smooth, light brown to yellowish grey; inner bark cream-green; exudate thin, watery; wood soft, creamy straw.

Cassava can be propagated by stem or seed. For agricultural purposes, the crop is propagated exclusively from cuttings to ensure true-to-type cultivars. Seed germination is usually less than 50 percent, and seed propagation also takes a longer time to establish. Botanically seeds are used only for breeding purposes (Sadik, 1988).

The radicle of the germinating seed grows vertically downwards and develops into a tap root from which adventitious roots originate. Later the tap root and some of the adventitious roots develop into storage roots (Sadik, 1988). Plants grown from stem cuttings have adventitious roots that arise from the basal root surfaces and occasionally from the buds under the soil. These roots develop into fibrous root system and only a few of them (3-6) bulk and become storage root, which require 9– 18 months to grow to harvestable size and can be 5–10 cm in diameter and 15–30 cm long.

The roots are covered with a thin reddish brown fibrous bark that is removed by scraping and peeling. The bark is reported to contain toxic hydrocyanic (prussic) acid, which must be removed by washing, scraping and heating.

2.4. Growth Requirements

Cassava is cultivated over a wide range of edaphic and climatic conditions between 30^0 N and 30 ^{0}S latitude, growing in regions from sea level to 2000-2300m altitude. Cassava grows well, mostly in areas considered marginal for other crops, for example low soil fertility with a pH range of 4-9 (Manu-Aduening *et al*., 2005). In general, the crop requires a warm humid climate. Temperature is important, as all growth stops at about 10ºC. Typically, the crop is grown in areas that are frost free all year round. The highest root production can be expected in the tropical lowlands, below 150 m altitude, where temperatures average 25-27°C but some varieties grow at altitudes of up to 1 500 m. The crop can, however, tolerate a temperature range of 16 ºC – 36 ºC (Cock, 1984).

The plant produces best when rainfall is fairly abundant and can be grown where annual rainfall is as low as 500 mm in semi-arid tropics and as high as 5,000 mm in sub-humid and humid tropics, but for best performances the crop requires a warm humid climate with a well distributed rainfall of 1000mm to 2000 mm per year (Akinpelu *et al.*, 2011). The crop can stand prolonged periods of drought in which most other food crops would perish. This makes it valuable in regions where annual rainfall is low or where seasonal distribution is irregular. In tropical climates, the dry season has about the same effect on cassava as low temperature has on deciduous perennials in other parts of the world. The period of dormancy lasts two to three months and growth resumes when the rains begin again.

Cassava grows well on many soil types ranging from light to heavy; however, deep, well drained, friable sandy loam to loamy soils are ideal for better root development. When planted on sandy soils, measures should be put in place to minimize soil erosion. The soil should also contain some amount of organic matter with a depth of 30-40 cm, well-drained soil, with clay content less than 18 % since the crop does not tolerate saline conditions. Cassava is adapted to varying degrees of temperatures, photoperiods, solar radiation and rainfall.

2.5. Diseases and Pests of Cassava

The largest number of cassava diseases is found in Latin America and the Caribbean, the plant's centre of origin, according to FAO (2013), however, many of them are now found in sub-Saharan Africa and Asia. Many diseases are caused by pathogens, whose damage symptoms appear on the leaves, stems and storage roots (Miskito *et al.,* 2000).

The common diseases of cassava are: cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, cassava bud necrosis and root rot. Some of these diseases attack the leaves and stems of cassava plants while others attack the storage roots (Olugbenga *et al.,* 2011; Miskito *et al.,* 2000).

2.5.1. Leaf and Stem Diseases

According to Miskito *et al.* (2000), common leaf and stem diseases of cassava are: cassava mosaic, cassava bacterial blight, cassava anthracnose, cassava bud necrosis and brown streak.

2.5.1.1. Cassava leaf mosaic disease

Cassava mosaic disease is caused by the African cassava mosaic virus which occurs inside the leaves and stems and causes yield reductions of up to 90 % (IITA, 2008). In the mid-1990s, an unusually severe form of CMD caused yield losses of 80 to 100 percent in parts of Kenya and Uganda (FAO, 2013). The leaves become discoloured with patches of normal green colour mixed with light green, yellow and white area (chlorosis). When cassava mosaic attack is severe, the leaves become very small and distorted and the plants are stunted (Kumar and Legg, 2009). The symptoms are more pronounced on younger plants, usually under 6 months, than older plants. The disease is spread through infected cuttings and by whiteflies –*Bemisia tabaci* (Alvarez *et al.*, 2012).

2.5.1.2. Cassava bacterial blight (Xanthomonas campestrispv. manihotis) It is caused by a bacterium which occurs inside cassava leaves and stems. Damage appears as water-soaked dead spots (lesions). The lesions occur between leaf veins and are most evident on the lower surfaces of the leaves (Alvarez *et al.*, 2012).

The symptoms are more evident in the wet than in the dry season. The disease is spread naturally by raindrops which splash the bacterium from infected plants to healthy ones (Miskito *et al.*, 2000). Insects, for example, grasshoppers become contaminated with the bacterium and spread it to healthy cassava plants. The disease is more severe in young plants than in older ones (IITA, 2004). The disease is mainly spread through infected cuttings. Dead cassava stems and leaves with the bacterium also serve as sources of the disease, if they are not destroyed after root harvest and can cause yield losses of 20 to 100 % (FAO, 2012).

2.5.1.3. Cassava anthracnose disease

Cassava anthracnose disease is caused by a fungus which occurs on the surface of cassava stems and leaves (Alvarez *et al.*, 2012). Cassava anthracnose disease appears as cankers (sores) on the stems and bases of leaf petioles. Cankers weaken the petioles so that the leaf droops downwards and wilts (Yaninek *et al.*, 2000). The wilted leaves die and fall causing defoliation and shoot tip die-back or complete death of the shoot. Soft parts of cassava stems become twisted under severe attack by the disease. The disease usually starts at the beginning of the rains and worsens as the wet season progresses (Alvarez *et al.*, 2012).

The main sources of the fungus that causes cassava anthracnose disease are cassava plants with the disease (FAO, 2012). The fungus spreads by wind carrying spores from cankers on the stems, or by planting stem cuttings with cankers. Dead cassava stems and leaves with the fungus also serve as sources of the disease, if they are not destroyed after root harvest (CIAT, 2006).

2.5.1.4. Leaf spot diseases

Cassava leaf spot diseases are caused by fungi. There are three different types, namely white leaf spot, brown leaf spot, and leaf blight. Cassava white leaf spot disease appears as circular white or brownish-yellow spots on the upper leaf surfaces. The spots sometimes have purplish borders around them (FAO, 2013). Cassava brown leaf spot disease appears as small brown spots with dark borders on the upper leaf surfaces. The brown spots occur between leaf veins, and their sizes and shapes are limited by the distance between these veins. Under severe attack the infected leaves become yellow, dry and die prematurely (IITA, 2008).

According to Miskito *et al.* (2000), Cassava leaf blight disease appears as light brown lesions on the upper surfaces of the leaves. The lesions are not limited by veins; therefore they are usually larger than brown leaf spots. The lesions may enlarge to cover most of the leaf surface and cause leaf blighting. Infected cassava leaves on the plant or those fallen on the ground are the main sources of the fungi that cause leaf spot diseases. The fungi spread to new plants from these sources by wind or rain splashes (FAO, 2013).

2.5.2. Stem and Root Diseases

2.5.2.1. Cassava brown streak disease

Cassava brown streak disease is caused by a virus. Presently, the disease is reported only from cassava growing regions in East and Southern Africa (Kumar and Legg, 2009). In 2011, FAO warned that none of the cassava varieties grown by farmers in the region seemed to be resistant to CBSD (Kumar and Legg, 2009; FAO, 2013).

Cassava brown streak disease appears on the leaves, stems and storage roots of cassava plants. On the leaves, the disease appears as patches of yellow areas mixed with normal green colour. The yellow patches are more prominent on mature leaves than on young leaves (IITA, 2008). On the stems, the disease appears as dark brown "streaks" with dead spots on leaf scars. These streaks are most prominent on upper, green portions of the stems. Cassava brown streak disease distorts the shape of the storage roots and may cause cracks and discoloration in the storage roots.

The main sources of the virus that causes cassava brown streak are cassava plants with the disease. The disease is spread through the planting of stem cuttings from diseased plants. The virus is also believed to be spread from plant to plant by insects (Yaninek *et al.*, 2000).

2.5.2.2 Cassava root rot diseases

Cassava root rot diseases are caused by various kinds of fungi living on or in the soil. The fungi occur mainly in soils that do not drain properly and in forest fallow land that has been recently cleared (Miskito *et al.,* 2000). The leaves on cassava plants affected by root rot disease turn brown, wilt and the plant appears scorched. The leaves may or may not remain attached to the plant, but the plant loses a lot of water and dies. Root rot diseases kill both feeder and storage roots of cassava. The storage roots may swell unusually and develop light brown coloration (FAO. 2013). The roots may give out a bad odour as they rot.

The important sources of cassava root rot fungi are soils, cassava root and stem debris contaminated with the fungi. The fungi enter cassava plants through wounds caused by pests or farming tools or by piercing the roots by themselves (Miskito *et al*., 2000). Farm tillage tools used in cassava farms with the disease should be cleaned after use to prevent the fungi on them from spreading to other areas. Similarly, cassava plant debris on farms with the disease serve as sources of root rot fungi and should be destroyed by burning (Yaninek *et al.,* 2000).

2.5.3. Pests

The major pests of cassava in sub-Saharan Africa are the cassava mealybug, the cassava green mite, the variegated grasshopper, whiteflies and vertebrate pests (rodents). Some feed on the leaves and stems while others feed on the stems and roots (Olugbenga *et al.,* 2011).

2.5.3.1. The cassava mealybug (Phenacoccus manihoti)

The cassava mealybug (*Phenacoccus manihoti*), reduces the lengths of the internodes and causes the leaves to clump together into 'bunchy tops'. The insect survives on cassava stems and leaves and is easily carried to new field. It can drastically reduce leaf and root yield, sometimes by as much as 80 % (IITA, 2008). Yield loss in infested plants, according to FAO (2013) can be up to 60 percent of the roots and 100 percent of the leaves.

2.5.3.2. The cassava green mite (Mononychellus tanajoa)

The pest causes tiny yellow chlorotic leaf spots, the size of pin pricks, on the upper leaf surfaces. Heavily attacked leaves become stunted and deformed. The cassava green mite causes the severest damage to cassava in Latin America and sub-Saharan Africa, especially in lowland areas with a prolonged dry season (FAO, 2013). Severe mite attack can result in 13 to 80 % loss in cassava yield (Olugbenga *et al.*, 2011)

2.5.3.3. The variegated grasshopper (Zonocerus variegatus)

It chews leaves, petioles and green stems. It feeds on the plant leaves and the bark of the stems. The pest damage is more common in older cassava plants than younger plants and is particularly severe during the dry season (IITA, 2008).

2.5.3.4. White flies

White flies feed directly on young cassava leaves and are also a virus vector, making them probably the most damaging insect pest in all cassava-producing regions (FAO, 2013). Two species of whiteflies mainly cause damage to cassava. Spiraling white flies (*Aleurodicus dispersus)* damage cassava by sucking sap from the leaves (Alvarez *et al*., 2012). As they feed, they secrete large amounts of honeydew that supports the growth of black sooty mould on the plant, causing premature fall of older leaves (Olugbenga *et al*., 2011). Bemisia white flies (*Bemisia tabaci*) also suck sap from the leaves, but this does not cause damage to the plant. However, as they feed, the insects inject viruses into the plant, and thus transmit the cassava mosaic disease, one of the most important limiting cassava diseases in Africa.

2.5.3.5. Termites

Termites chew and eat stem cuttings, causing the cassava to grow poorly and die or rot. Many different kinds of termites damage cassava stems and tubers. Others include: Cassava root scale (Stictococcus vayssierrei) and cassava white scale (Aonidomytil usalbus) which cause the tubers to be smaller and deformed, and stems to lose a lot of water and die respectively (Alvarez et al., 2012).

2.5.3.6. Vertebrate pests

Birds, rodents, monkeys, pigs, cattle, goats and sheep are common vertebrate pests of cassava. These pests, especially grass cutters (also known as cane rats), defoliate the crop by eating the leaves, green stems and roots after bulking and during late harvest.

2.6. Weed Control

Weeds are plants growing where they are not wanted (Melifonwu *et al*., 2000). Many different types of weeds occur in cassava farms and cause considerable losses to the farmer. Weeds can reduce cassava yields by competing with the cassava crop for moisture, nutrients, space and light (African Organic Agriculture Training Manual, 2011).

The initial growth of cassava is slow in the first 3 to 4 months and coupled with relatively wide spacing between plants, gives weeds a chance to emerge and compete favourably for sunlight, water and nutrients (FAO 2013). Weeds may also harbour pests and diseases or physically injure cassava plants and root tubers. Common weeds affecting cassava production in Africa are: narrow leaf feathery Pennisetum

(*Pennisetum polystachion*), spear grass (*Imperata cylindrica*) and guinea grass (*Panicum maximum*), *Cyperus rotundus* and broadleaf weeds such as (*Chromolaena odorata*), and goat weed (*Ageratum conyzoides* (Melifonwu *et al.*, 2000).

Weed competition in the first four months after planting may result in yield reductions of approximately 50% (Leihner, 2002). In most African countries, farmers spend more time on weeding than on any other aspect of crop production (Olorunmaiye, 2010).

Once the cassava canopy has closed, it will shade out most weeds and keep the field almost completely weed-free (FAO, 2013). Six to eight months after planting, weeds may reappear, but this generally does not seriously affect yields but rather make harvesting more difficult.

Cultural practices can provide an effective defense against weeds. While cultural controls may not be 100 percent effective, they do help in reducing weed competition, and thus the need for mechanical or chemical weeding (Leihner, 2002). Cultural control begins with selection of high-quality planting materials from varieties with vigorous early growth and tolerance or resistance to important diseases and pests. High planting density and the recommended type and rate of fertilizer, applied in short bands next to the planted stakes, can stimulate early crop growth and rapid canopy closure (FAO, 2012).

Many cassava farmers in sub-Saharan Africa use mechanical control measures by removing weeds with hoes, about 15 days after planting. Research in Colombia, found that with hand-weeding at 15, 30, 60 and 120 days after planting, cassava root yields were 18 tons per ha, only 8 percent less than those obtained when weeds were controlled with herbicides. When weeds were not controlled at all, yields fell to just 1.4 tons (Leihner, 2002).

Weeds are often controlled with herbicides on commercial farms, when labour is unavailable or too expensive. Pre-emergence herbicides when applied prevent weed seeds in the soil from emerging or reduce their rate of growth (Melifonwu *et al.,* 2000). The application of pre-emergence herbicides can maintain a cassava field almost weed-free for 6 to 8 weeks after planting (FAO, 2013). At about two months after planting, weeds may need to be controlled again to reduce competition with cassava. This is usually done by hoeing or using an animal or tractor mounted cultivator, depending on the height of the growing cassava plants and the extent of canopy closure. It is also possible to apply a selective post-emergence herbicide; to control weeds about 4 to 5 months after planting, when some bottom leaves start to drop off**.**

2.7. Uses of cassava

2.7.1. Human Food

According to FAO (2004), the utilization of cassava globally was estimated at 102 million tons in 2000, with Africa consuming the bulk of fresh roots and processed products. In many parts of Brazil, fresh roots are grated and the liquid, which contains much of the roots' cyanide content, is pressed out. The semi-dry mash is then roasted to produce *farinha*, coarse flour that is spread on many Brazilian dishes (Howler, 2012; Balogoplan, 2004).

In Indonesia, peeled roots are sliced lengthwise then sun-dried and called *gaplek* (FAO. 2012). When needed, *gaplek* is pounded into flour, which is swirled around with a little water to produce small granules called *tiwul*, the size of rice grains, steamed and eaten as a "rice extender" when there is not enough rice to feed the family (Howler, 2012). A popular snack in Indonesia, called *krepek*, is made by washing peeled roots and thinly slicing them with a hand or electric slicer. The slices are placed in cold water, drained and then fried in hot oil for a few minutes.

Since its introduction in Africa in the 16th century, cassava has become one of the most important crops on the continent. Production has more than tripled in the last four decades (Hillocks, 2002) and the crop is currently grown on approximately 12 million hectares. As food, feed and industrial markets are promising; there is an increasing focus on cassava by governments, research and development institutes in
Africa (FAO, 2004).

Young cassava leaves are regularly picked and cooked for human consumption in several African countries, including Cameroon, the Democratic Republic of the Congo, Liberia and Tanzania. The tender leaves contain up to 25 percent protein, on a dry matter basis, and are a valuable source of iron, calcium, and vitamins A and C (Balagoplan, 2004).

In Africa, grated roots are fermented before being roasted on a hot plate to produce granulated flour called *gari*, or milled into flour, which is mixed with water to produce stiff dough called *fufu*. Steaming is used in Côte d'lvoire and Benin to make another granulated cassava product, called *attiéké*. In the Democratic Republic of the Congo, pounded cassava flesh is wrapped in banana leaves and steamed for several hours to make cassava bread or sticks, called *chick- wangue*or *kwanga*, which are served with soups, stews and sauces (FAO 2012; Balagoplan, 2004).

Cassava plays a famine prevention role wherever it is cultivated. Lancaster and Brooks (1982) stated that famine rarely occurs in areas where cassava is widely grown because it provides a stable base to the food production system. The importance of cassava in Ghana cannot be over emphasized. It is principally used as a human food. Cassava is eaten boiled, baked, fried, or pounded or in numerous processed forms (Lancaster and Brooks, 1982). Doku (1969) observed that cassava root could be used to prepare *ampesi, kokonte, akyeke, garifoto, akple, gari, tapioca, starch, yakayake, agbelikaklo* and *fufu* in Ghana. The Ewes in Ghana have named the cassava crop "*agbeli*" meaning there is life. This in no doubt portrays its importance to the whole country and the Ewes in particular who are found in almost every part of the country which stands supreme as cassava growers (Doku, 1969). The *fufu* groups include *amala* in Nigeria, *toh* in Guinea, *fufu* in Zaire, Congo, Cameroon and Gabon; *ugali* and *kowon* or *atap*in Uganda and Tanzania respectively; *nchima* in Mozambique, *nsima* in Malawi, *ubugali* in Rwanda and *funge* in Angola (Hahn and Keyser, 1985). Some of the most common cassava based foods in Africa apart from those of Ghana are *abacha, elubon, lafun* and *kpokpogari* in Nigeria. In Cameroon some of the dishes are *baton du manioc, chickwangue, kouron-kouron* and *kumkum.* Other dishes include *attieke* in Cote d`lvoire, *foofoo* in Sierra Leone, *njambo* in Gambia and *ugali* in Tanzania (IITA, 1990).

High quality cassava flour is cassava a cassava product that has not been fermented and can be used as an alternative to wheat flour and other starches in bread and confectionary (Westby and Adebayo, 2012). Native starch is extracted from cassava roots in some countries, mainly in Asia, and used in food products. If properly extracted, cassava starch is pure white, with low levels of fat and proteins and a noncereal taste, which is desirable in many food products (FAO, 2012).

In some parts of India, wet starch is collected, crushed and shaken on a hemp cloth to form small starch balls, which are sieved and steamed for a few minutes to form *tapioca* pearls (Westby and Adebayo, 2012; Balagoplan, 2004). In Indonesia, cassava starch is mixed with shrimp paste, food colouring and water and then extruded and thinly sliced by hand. The slices are steamed on bamboo screens for a few minutes, after which they are sun-dried on a patio floor for half a day, producing hard chips known as *krupuk.* When deep-fried, *krupuk* swell into brittle soft crackers, which are a popular snack that accompanies almost every meal.

Starch extraction produces a considerable quantity of useful residues. Root peelings can be recycled as fertilizer and animal feed. Once dried, the discarded fibre can be sold as flocculent to the mining industry, while low-density starch lost during sedimentation is used as pig feed (Buitrago, 2012; FAO 2012).

2.7.2 Animal feed

Both the roots and leaves of the cassava plant can be used as on-farm animal feed or as an ingredient in commercial animal feed (Howler, 2012). Because of their high cyanide content, however, fresh roots or leaves can be fed to animals only in very small quantities. Cassava roots are chipped or sliced, while leaves are chopped into small pieces. The chopped pieces of roots and leaves can be sun dried or packed tightly in plastic bags or air-tight containers and fermented to make silage (Howler, 2005). Both sun-drying and ensiling will release most of the cyanide, making those products safe as feed for pigs, cattle, and chickens.

Chips are sold directly or milled into a powder that can be mixed with other ingredients such as soybean meal, full-fat soybeans, fishmeal or other protein sources to make a nutritious animal feed that is usually supplemented with methionine, vitamins and minerals. When the diet is well-balanced, in terms of energy and protein, the performance of pigs is very similar to that obtained with a diet based on maize or broken rice (Balagoplan, 2004). Cassava meal is highly digestible and naturally contains lactic acid bacteria and yeast, which improve the micro-flora in the digestive tract of animals. At low levels, hydrogen cyanide in cassava feed increases the efficiency of an enzyme, lactoperoxidase, which is a natural antibiotic that kills mycotoxins in the animal's body and milk (Howler, 2012). Animals raised on cassava diets have generally good health, good disease resistance and a low mortality rate and require few if any antibiotics in their feed are needed (Howler 2005).

Dry cassava leaf meal or cassava hay is mostly obtained by cutting the plant tops at 2.5 to 3-month intervals during the cassava growth cycle (Howler, 2012). It contains high fibre content and is suitable mainly for ruminants. According to Balagoplan, (2004) supplementation with 1 to 2 kg of cassava hay per animal per day increases the milk yields of dairy cows and boosts levels of thiocyanate in the milk, which may boost milk quality and storability. Condensed tannins in the foliage meal also reduce gastro-intestinal nematodes, indicating that the meal may act as an anti-helminthic agent (Howler, 2008). In broilers, the inclusion of cassava foliage meal is useful mainly as a natural pigmenter. The high content of xantophyll pigments (500-600 mg/kg) improves the colour of skin in broilers and that of egg yolks (Buitrago, 2012). Leaf silage is made by mixing chopped leaves with 0.5 percent salt and 5 to 10 percent cassava root meal which contains about 21 percent crude protein and 12 percent crude fibre (FAO, 2013).

2.7.3. Industrial uses

In Asia, much of the native cassava starch is processed into a range of modified starches, for incorporation in food products or use as feedstock for production of sweeteners, fructose, alcohol and monosodium glutamate. Along with high quality cassava flour, modified starch is also used in the manufacture of plywood, paper and textiles in large quantities (Balagoplan, 2004). Fresh roots or dried cassava chips are increasingly, being used for production of fuel ethanol. It can be blended with gasoline to produce "gasohol" with 10 percent, 20 percent or even 85 percent ethanol (FAO, 2012).

According to IITA (1990), cassava starch is used in the food industry in many preparations including sauces, gravies, mustard powder, baby foods, tapioca products, such as puddings, infants and invalid foods; glucose production, confectionaries and bakery products as well as jelly or thickening agent in the manufacture of adhesives, dextrin and paste and as filler in the manufacture of paints.

Glucose, unmodified and modified starch are used in the food industry for one or more of the following purposes: directly as cooked starch food, custard and other forms; thickener using the paste properties of starch (soups, baby foods, sauces and gravies; filler contributing to the solid content of soups, pills and tablets and other pharmaceutical products, fee cream; binder, to consolidate the mass and prevent it from drying out during cooking (sausages and processed meats); and stabilizer, owing to the high water-holding capacity of starch (FAO, 1977).

In the textile industry, cassava is used for warp sizing, cloth and felt finishing and printing. Minor industrial applications include the use in the manufacture of explosives, dyes, drugs, chemicals, carpets, and linoleum and in the production of alcohol and the coagulation of rubber latex (Kay, 1987). An important new application of starch is in the machine-coating of magazine paper, formerly done exclusively with caseins (Ceballos *et al*., 2012).

Before the Second World War the manufacture of plywood and veneer relied mainly on cassava as a glue. The basic material in this case is gelatinized at room temperature with about double the amount of a solution of sodium hydroxide. Particle board from cassava stalks is made from cassava stalks due for disposal, by Tropical Products Institute, London by cutting them into small sections and mixing with resins (Ceballos *et. al.*, 2012).

Cassava is one of the richest fermentable substances for the production of alcohol in Africa, Asia and Latin America. The fresh roots contain about 30 percent starch and 5 percent sugars, and the dried roots contain about 80 percent fermentable substances which are equivalent to rice as a source of alcohol (FAO, 1977). In Ugandan cassava beer and fermented drinks such as*beiju*, *banu*, or *Ula* and *Kasili*, are made after fermentation of grated cassava and are common in the tribal belts of South America (Lancaster and Brooks, 1982). While barley doesn't do well in the tropical climate, cassava is so easy to grow in Africa. The crop hadn't been used in beer because it starts to degrade within 24 hours of harvesting; however with new technology from SABMiller an initial processing of the roots in the field, allows them to be stored for weeks (Dontoh and Kew, 2013).

2.8. Nutrients Requirements of Cassava

Cassava can grow and produce reasonable yields on soils where many other crops would fail; however there is no doubt that fertilizer can increase cassava yields. Cassava is a heavy potassium feeder, but also requires nitrogen, phosphorus and other micro nutrients to produce good yields (Howler, 2008).

At early stages of cassava growth equal amounts of N, phosphorus pentoxide (P_2O_5) and potassium oxide (K_2O) at a rate of 500 kg to 800 kg per ha of a compound fertilizer such as 15-15-15 or 16-16-16 NPK should be applied. Intensive cassava cultivation on the same land, leads to massive nutrient removal; therefore N-P-K balance will need to be modified to compensate for the corresponding removal of each nutrient in the root harvest by applying fertilizers with a ratio of N, P_2O_5 and K_2O of about 2:1:3, or 2:1:2 or any compound fertilizer that is high in K and N, and relatively low in P and sometimes applied in combination with manure (Nguyen *et al*., 2001; CIAT, 2009; FAO, 2013)

Soluble fertilizers such as urea, single and triple superphosphate, diammonium phosphate, potassium chloride and potassium sulphate and most compound fertilizers should be applied either when the cuttings are planted or, preferably, about one month later, when the roots have emerged (Howler, 2008). Phosphorus should be applied at or shortly after planting. N and K are best applied in split doses, one half at or shortly after planting, and the rest at 2 to 3 months after planting, when cassava reaches its maximum growth rate (FAO, 2012). An excess of N fertilizer may over stimulate vegetative growth at the expense of root production in some cassava varieties (Fermont *et al*., 2009).

Howler (2002) observed that cassava, like any root crop, required great amounts of potassium for optimal production. Continuous cassava production, without fertilization, will inevitably result in K becoming the most limiting nutrient. Compared with other crops, cassava forms extensive associations with mycorrhizal fungi in the soil (Fermont *et al.*, 2009). These associations help the plant in the uptake of especially phosphorus, a low mobile element in the soil, by increasing the explored soil volume. As a result, cassava has a much lower critical level for available P than less mycorrhizal dependent crops like maize and beans. Cassava grows well on soils with a relatively weak capacity to supply P (Fermont *et al.*, 2009; Howler, 2000). Responses to P fertilizer depended on the available P supply, the mycorrhizal infection potential of the soil and the fine root length and shoot or tuberous root balance of the cassava genotype (Pellet and El-Sharkawy, 1997).

In addition, cassava is well adapted to acidic soils due to its tolerance to low pH and exchangeable aluminum (Howler, 2002). For this reason, cassava may not require large amounts of lime in acid soils, where other crops would not grow without them (FAO, 2013). The crop is however sensitive to zinc (Zn) deficiency, especially during early growth stages (Howler, 2002).

Research in comparing cassava with other crops, found that nitrogen (N) and phosphorus (P) removal per hectare by cassava roots was lower than for the harvest products of most other crops, while potassium (K) removal was substantially higher in case of high cassava yields (36 t ha^{-1}) and similar to other crops in case of moderate cassava yields (11 t ha^{-1}) according to (Putthacharoen *et al*., 1998; Fermont *et al.*, 2009). Most of the nutrients absorbed by cassava during growth are found in the plant above ground biomass (Howler, 2005). FAO (2013) reported that a root yield of 15 tons per ha removes only about 30 kg of nitrogen, 20 kg of potassium (K) and just 3.5 kg of phosphorus (Howler, 2001).

2.9. Effects of Inorganic fertilizer application on growth, yield and root quality of cassava

The ability of the cassava plant to produce substantial yield on low fertility soils has given rise to the misconception that cassava does not require, nor even respond to, the application of mineral fertilizer. When cassava root yields are high and crop residues are not ploughed back into the soil, cassava harvest removes large quantities of nitrogen and potassium. To sustain yields and soil fertility, cassava would require per hectare annual applications estimated between 50 to 100 kg of nitrogen, 65 to 80 kg of potassium and 10 to 20 kg of phosphorus, depending on inherent soil fertility and yield levels desired (FAO, 2013),

According to Uwah *et al.* (2009) plant height, the number of leaves, branches as well as stem girth were significantly increased by the application of NPK. Various research findings showed superior growth attributes obtained with relatively high rates of NPK (NRCRI, 2005). The positive response of growth characters to the applied nutrients is attributable to their role in cell multiplication and photosynthesis which gave rise to increase in size and length of leaves and stems. The favourable response also confirmed the essentiality of N and K in plant growth and development (Mengel and Kirkby, 2001). This result is in harmony with the findings of Nguyen *et al*. (2001) and Ayoola and Makinde (2007). Okogun *et al*. (1999) reported of an early branching and increase in number of branches per plant as important, to expose the leaves to sunlight for photosynthesis and increased translocation for higher photosynthates accumulation. Increased branching may also suppress weeds.

Ramanujam and Indira (1987) observed an increase in plant growth characteristics at higher levels of K application in cassava. Maximum growth rates of leaves, flowers, stems, canopy size, branching habit and dry matter partition to leaves and stems are accomplished between the growth periods of 90-180 DAP (Tavora *et al*., 1995) and the most active vegetative growth for cassava according to (Ramanujam and Indira, 1987). Local farmers over the years have been using root dry matter as an index for cultivating particular varieties that suit their food needs for *fufu, ampesi* and others (Adoa, 2009).

Susan *et al.* (2005) observed that no K application resulted in stunted plant growth, elongated stems with more number of leaves, lower plant biomass and lower crop growth rate compared to K application. Potassium is essential for carbohydrate translocation from top to the roots and inadequate supply of K for cassava will thus, lead to excessive top and little root production (Obigbesan, 1977).

In Thailand, high root yields of up to 40 tons per ha were maintained when adequate amounts of mineral fertilizer (100 kg N + 22 kg P + 83 kg K) were applied annually and when no fertilizer was applied, per hectare yields declined sharply, from 30 tons in the first year to about 7 tons after six years, owing to nutrient depletion, especially of potassium (Howler, 2012).

Cassava yields in Africa could be increased markedly if farmers had access to mineral fertilizer at a reasonable price (FAO, 2013). In the Democratic Republic of Congo, per hectare cassava yields increased from 12 to 25 tons with moderate applications of N-P-K fertilizer, and reached more than 40 tons with higher application rates including stem yields, important for production of high quality planting material (FAO, 2012).

Evangelio *et al.* (1995) reported significant yield increases in cassava due to N and K fertilization. Both N and K are essential for cassava root initiation; increase in tuber size and number (Howler *et al.*, 2000; Ayoola and Makinde, 2007). Nitrogen increases the chlorophyll of leaves thereby promoting the photosynthetic capacity of the plant, plays a part in the manufacture of proteins and is also responsible for high yield in plants. Phosphorus, on the other hand, promotes CO_2 assimilation and the translocation of carbohydrates from leaves to the tubers and tuberous roots of crops where carbohydrates are the main storage material (Mengel and Kirkby, 2001). Susan *et al.* (2005) studied the effect of K application on root yield of cassava and observed that K

nutrition profoundly influences the number of storage roots and mean tuber weight per plant. Susan *et al.* (2005) further reported of an increase in the number of tubers per plant and tuber size with an increase in K_2O application rates up to 200 kg/ha. A long-term fertiliser experiment showed that continuous
cultivation of cassava with only N or P fertilisers reduced the tuber yield.

It has been observed that high application of P increased yield of cassava while yield decreased at high application of nitrogen. Apart from increasing yield, high K application has been shown to improve dry matter and starch content and reduce the hydrocyanic acid content of cassava roots (Uwah *et al.*, 2009). Influence of source size on dry matter production shows that the storage root growth rate is reduced when the source size is increased from leaf area index 3.0 to 6.0 (Ghosh *et al*., 1988).
Adoa (2009) reported of a strong positive correlation between dry matter content and starch content. Safo-Kantanka and Asare (1993) reported that root dry matter could only explain 40% of variation in starch yield in cassava. Starch quality, is dependent on the solubility, swelling power and water binding capacity (Baafi, 2005). Parkes *et al*. (2012) observed significant differences in starch content between the various genotypes and fertilizer rates over the control.

Adequate supply of K is important for starch synthesis and translocation and it also increases yield and improves root quality (Mehdi *et al*., 2007). It is well known that K plays a significant role in the synthesis and translocation of carbohydrates and as a catalyst for activating a number of enzymes involved in the synthesis of starch, protein and glycosides. Potassium has a moderating effect on improving the root quality by increasing the starch content and reducing the cyanogenic glucoside responsible for bitterness in cassava (Susan *et al*., 2005), Thus, increase of starch content, and other starch quality parameters like amylose content, granule size, pasting temperature, viscosity and swelling volume also increased with increase in K application rates.

2.10. Effects of Organic fertilizer application on growth, yield and Root Quality of cassava.

Among the various types, chicken manure tends to have the highest nutrient content (Susan *et al*., 2005). Manure and compost are both good sources of organic matter which, when incorporated into the soil, improve its structure and aggregate stability, and enhance water holding and cation exchange capacity. They also facilitate the below-ground biological activity of earthworms, bacteria and fungi, and supply a wide range of nutrients, including secondary and micro-nutrients.

Application of poultry manure has various advantages such as increasing soil physical properties, water holding capacity, and organic carbon content apart from supplying good of nutrients (Ayoola and Adeniyan, 2006**).** Nutrient supplied by poultry manure enhances increase in plant height due to increase in cell elongation of plant tissues as a result of steady release and mineralization of nutrients (Sharma and Govil, 1988; Christopher *et al*., 2007). Adoa (2009) reported highest plant height with the application of poultry manure on *Nkabom* and IFAD cassava varieties. Adjei-Nsiah and Issaka (2013) observed that average fresh tuber yield increase from 13.7 t/ha without amendment to 23.7 t/ha with application of 4 t/ha poultry manure. Organic fertilizer promote the growth of stems and leaves of cassava, increase the chlorophyll content and the photosynthesis of leaves and improve the physiological metabolism of cassava (Luo *et al*., 2008).

The period of maximum rate of dry matter partitioning depends on genotype-byenvironmental interaction (Fregence *et al*., 1994). Canopy spread in cassava ensures large surface solar interception for photosynthesis (Lebot, 2009). Tolessa and Friensen (2001) reported that 4 months after planting, the leaves of cassava are able to intercept most of the radiation falling on the canopy and it is the time when the maximum size of the canopy with the maximum dry matter partition of the leaves and stems are obtained. Howler (1990) further stated that greater foliage is created by the action of nitrogen and consequently an extensive assimilating area, a prerequisite for the good development of the root. Excessive foliate, though, may lead to shedding and other leaves serving as net users of photosynthates.

Manure also promote the photosynthetic organ to transfer to the roots and increase the yield and starch content in the root of cassava (Zhongyong *et al.*, 2006). Shafeek *et al.* (2012) observed that organic fertilizer promote stems and leaves of cassava growth, increase the chlorophyll content and the photosynthesis of leaves.

Application of manure in farming systems can help maintain consistently high yields of crops through improvements in water and nutrient use efficiencies and soil biotic activity and organic matter levels. Higher root yield following the application of organic fertilizer is attributed to favourable changes in soil, such as loose and friable soil conditions, enabling better root formation, as well as slow and steady availability of nutrients throughout the crop growth period (Amanullah *et al.*, 2006).

The distribution of dry matter to the economically useful plant parts is measured by harvest index which represent the efficiency of storage root production (Alves, 1998). Significant differences in harvest index have been reported among cultivars, indicating that it can be used as a selection criterion for higher yield potential in cassava (Tavora *et al*., 1995).

Organic manure also improve the water holding capacity of the soil; improve the soil structure, the soil aeration and impact positively on growth, yield and tuber quality of cassava (Ayoola and Makinde, 2007). Luo *et al*., (2008) added that organic fertilizer improves the physiological metabolism of cassava and also promote the photosynthetic transfer to the root and increase number of root, yield and starch content in the tuber root of cassava. In a study to investigate yield performance of five cassava genotypes under different fertilizer rates, Parkes *et al*. (2012) observed that the number of roots per plant was significantly influenced by fertilizer treatments. An increase in the number of storage roots per plant in response to organic fertilizer application has been reported by Kasele (1980) and Pellet and ElSharkawy (1997). Leo and Kabambe (2014), observed a significant increase in number of root per plant, and tuber diameter having a positive correlation with fertilizer treatment. They further observed that an increased root diameter and length is important for the markets.

Shafeek *et al.* (2012) concluded after series of research that addition of manure to the cassava plant caused an increase of the nutritional elements in rooting zone; consequently the more nutrients were absorbed to enhance the growth of the plant. Manure also increased availability of nutrients especially N, P, K, Zn, Fe and Mn even from the early stages of crop growth. Manure application has resulted in higher root yields of cassava (Wilson and Dufour, 2002; Agbaje and Akinlosotu, 2004; Issaka *et al*., 2007; Ojeniyi *et al*., 2012). Manure application enhances the cooking quality (mealiness) of cassava. Adoa (2009) reported that poultry manure treatment enhanced the cooking quality of cassava. Various observations have been made of a positive correlation between dry matter content and cooking quality of cassava. (Safo-Kantanka and Asare 1993; Safo-Kantanka and Owusu Nipa, 1992).

2.11. Combined effects of organic and inorganic fertilizer on growth, yield and root quality of cassava

While mineral fertilizer can help to boost yields, singly it cannot sustain crop production in the long-term on degraded land, therefore farmers need to maintain and improve soil quality and health using a number of other measures, such as conservation tillage, intercropping, green manuring, mulching crop residues and cover crops, alley cropping, and applying animal manure or compost in an integrated form (Pellet and El-Sharkawy, 1997).

Trials indicate that combining about 3 to 5 tons of manure or compost per ha with mineral fertilizer that contains the right balance of N, P and K is often the most effective means of increasing yields and maintaining the soil's productive capacity. The fertilizers supplied the bulk of the macronutrients needed by the plants, while the organic sources provide secondary and micronutrients which are only needed in very small quantities and improve the soil's physical conditions (FAO, 2012).

The steady and sustained release of plants nutrients over a relatively long period of time ensure vegetative growth of the cassava plant**,** thus promoting stem and leaf growth, increase the chlorophyll content and the photosynthesis of leaves (Howler, 2002). Complementary use of organic manures and mineral fertilizers is reported to be a good soil fertility management strategy in many countries of the world (Ojeniyi *et al.,* 2012).

High and sustained crop yield could be obtained with judicious and balanced NPK fertilization combined with organic matter amendments. Santhi and Selvakumari

(2000) have proposed that the addition of organic sources to chemical fertilizer could increase cassava yield through improving soil productivity and higher fertilizer use efficiency. This is supported by Ayoola and Makinde (2007) who suggested that an integrated nutrient management programme, in which both organic manure and inorganic fertilizer are used, is a rational strategy for crop improvement. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Tisdale *et al*., 1993).

A combined use will increase synchrony and reduce losses by converting inorganic N into organic forms (Kramer *et al*., 2002). It also reduces the environmental problems that may arise from the use of sole inorganic fertilizers and improves the microbial properties of the soil (Belay *et al.*, 2001). John *et al.* (2004) has advocated an integral use of organic manure and inorganic fertilizers for the supply of adequate quantities of plant nutrient required to sustain maximum crop productivity and profitability while minimizing environmental impact from nutrient use. The plant benefits from the combined attributes of both organic and inorganic fertilizers (Ayeni, 2008). The use of mineral fertilizer in combination with poultry manure has shown an increase yield as much as 60 t/ha of cassava roots (CSIR- AGRA, 2012).

2.12 Cost benefit of the use of fertilizer in cassava production

Cassava is one of the important crop in the tropical regions of the world after its introduction in the 16th century (Asare *et al.*, 2009). According to Hillocks (2002), cassava production has more than tripled in the last four decades and it is currently grown on approximately 12 million hectares.

Cassava is frequently cultivated on marginal soils (Dixon *et al.*, 2002). Hillocks (2002), suggested that the observed increase in acreage is related to declining soil fertility levels in Africa. According to FAO (2006), average cassava yields in Africa have gradually increased from 6 to 10 t/ha over the past five decades. At present, the average African farmer harvests approximately 20% less cassava per hectare than the world average 12.2 t/ha due to no or low fertilizer inputs.

Alves (2002) stated that cassava was a subsistence crop, grown by resource poor, small-holder farmers, who plant it preferably as an intercrop to reduce the risk of crop failure, while maximizing returns to land and labour. Cassava is also thought to require less labour than other crops and to be grown without inputs (Leihner, 2002). There is the need to take advantage of less labour cost and apply recommended fertilizers to increase crop yield, without necessarily increasing income to farmers.

Smallholder Foundation (2013) reported that cassava cultivation is about the cheapest because; it requires minimum cost of production. With or without fertilizer, cassava grows and produces root, though fertilizer enhances greater yield.

As the crop has assumed industrial status in Ghana, it is now being grown on a relatively large scale, repeatedly season after season on the same piece of land leading to reduction in soil fertility. There is the need to apply supplementary nutrients for sustainable crop production (Asare *et al.,* 2009). Given that Ghanaian producers are mostly small holders, fertilizer application would imply increase in the income levels of farmers. The financial attractiveness of an enterprise is, however, paramount to attracting new entrants (FAO, 2000).

In a tentative cost to establish one hectare of cassava farm, total production cost was estimated to be N 209,950, while total income was 412,500 Naira, giving a profit margin of N 202,550, with fertilizer cost estimated as N 30400 (Smallholder Foundation, 2013). In a study to assess the productivity and profitability of cassava in

Nigeria, Ogisi *et al.* (2003) showed that cassava production was profitable in Delta State of Nigeria. On the average, total revenue per hectare was N 81,468 while total cost per hectare was N 32.214 with a cost-benefit ratio of 0.40; thus the enterprise is seen to be viable. Gross margin per hectare was N 61901, Net farm income was N 49272 and Net return to investment (NRI) per Naira was approximately N 153.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Experimental Site

The experiment was conducted at the research fields of CSIR-Crops Research Institute at Fumesua in Ashanti Region (01° 36°W; 06° 43°N) from May 2014 to April 2015.

3.2. Climate and Vegetation

Fumesua is in the semi-deciduous forest zone with elevation of 186 m above sea level. The average annual rainfall is about 1700 mm and has a bimodal rainfall distribution. The major rainfall season is from March to July while the minor rainfall season is from September to November. The mean minimum and maximum temperatures are 21°C and 31°C, respectively. The mean annual relative humidity is 95% in the morning and 61% at noon. The soil at the experimental site at Fumesua belongs to the Asuansi series and is classified as Ferric Acrisol. It has 16-20cm thick layer of sandy loam and slope of 1-5 percent.

3.3 Rainfall data for June, 2014 to May, 2015.

The rainfall data for the period of study was obtained from the meteorological department at Fumesua.

3.4. Experimental design and treatments

The study was factorial experiment with three (3) varieties of cassava and four (4) organic and inorganic fertilizer levels. The treatments were arranged in randomized complete block design with three replications. The main plot measured 5 x 12 m, separated by a 2 m path. Each sub- plot measured 5 x 4m, separated by paths of 1.5

m. Each replication is separated by 2 m path and a general 2 m boarder around the whole experimental site. There were 36 plots with total gross plot size of 1254m^2 (19 x 66 m).

The fertilizer treatments were:

(i) F1– N-P_2O_5-K_2O at a rate of 30-60-60 kg/ha

(ii) F2 – Poultry Manure (PM) at a rate of 4t/ha,

(iii) F3 – ½ (N-P_2O_5-K_2O +PM)

(iv) F4 – Control

Varieties used were:

i. V1- Sika ii.

V2- Ampong.

iii. V3-Bankyehemaa.

3.5 Varieties used

***3.5.1. Ampong*:** This is an early maturing variety, maturing 12 months after planting, it is poundable and responds to soil fertility, however the environmental conditions. It contains about (22-27%) of starch, with an average yield between 20-50t/ha, depending on favourable environmental conditions and good agronomic practices. It branches early and grows vigorously with an average height of 3-4 feet above ground and good for intercropping. *Ampong* contains 60% water and have low dry matter as compared to landraces. High yield compensate for low dry matter. It is tolerant to African Cassava Mosaic Virus and its cyanide level is below the injurious point (Manu- Aduening, 2014; personal communication)

3.5.2. Sika: This has high starch content (26-33%) content depending on environmental conditions, moisture content, soil fertility and time of harvest. Yield ranges between 20-50t/ha, depending on rainfall, soil nutrient, moisture and other favorable environmental conditions. It branches early and grows vigorously with an average height of 3 feet above the ground and not good for intercropping. Maturity period is also affected by environmental factors and matures around 12 months. The variety responds to high soil fertility but affected by environmental conditions. *Sika* contains between 55- 60% water with low dry matter as compared to landraces. It is not poundable, poor mealiness and tolerant to African Cassava Mosaic Virus, with low Hydro-Cyanide level below injurious point (Manu- Aduening, 2014; personal communication).

3.5.3. Bankyehemaa: It has high starch content (26-33%) depending on environmental conditions such as moisture, soil fertility, time of harvest and responds well to high soil nutrients. Its cooking quality is affected by the time of harvest. It is generally described as not cookable and grown for its high starch. (Manu- Aduening, 2014; personal communication)

The planting materials were obtained from Crops Research Institute. The cuttings were planted one per stand, slanted at an angle of about 45^o with a spacing of 1m x 1m. Mineral fertilizers used were: Urea, Triple Super Phosphate and Muriate of Potash.

3.6. Cultural Practices

The land was slashed, ploughed and harrowed to control weeds. linning and pegging was carried out before planting. Planting was done on 30th May 2014, establishment count was done on 13th June 2014 and refilling carried out on 14th June, 2014.

Manure application was done 4 weeks after planting and NPK applied 8 weeks after planting. Four manual weeding were done at one, two, three and four months after planting. The N.P.K was applied at a rate of 30-60-60 kg/ha and poultry manure at a rate of 4t/ha. The manure was placed about 15cm around the plant while the NPK was placed 15-20 cm away from the plant to the direction of the roots.

3.7. Soil Sampling and Chemical Analysis

Soil samples were taken from top 0-30 cm and were bulked to have a composite sample which was analysed for chemical and physical properties. The samples were air-dried, crushed and passed through a 2 mm mesh sieve. Afterwards, routine analyses were carried out.

3.7.1 Soil pH

This was determined in distilled water at 1:1 soil to water ratio, using electrometric method.

3.7.2. Total Nitrogen

Total Nitrogen was determined by the macro- Kjedahl digestion method as described by Bremner and Mulvaney (1982). A 10 g soil sample which is less than 2 mm in size was digested with a mixture of 100 g potassium sulphate, 10 g copper sulphate and 1g selenium with 30mls of concentrated sulphuric acid. This was followed by distillation with 10ml boric acid (4%) and 4 drops of indicator and 15mls of 40% NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14g of nitrogen is contained in one equivalent weight of NH_3, the percentage of nitrogen in the soil was determined with the relation:

% Nitrogen 14 x (A-B) x N X 100/ 1000 x 1

Where,

A = Volume of standard acid used in the titration.

B = Normality of the standard acid

3.7.3 Soil organic carbon and Organic Matter

Organic Matter content was determined by Walkley-Black wet combustion procedure (Nelson and Sommers, 1982). Percentage Organic Matter was derived by multiplying % organic carbon by Broadbent's factor of 1.72 (Broadbent, 1953).

3.7.4 Available Phosphorous

This was determined by the Bray-1 P test, using 0.03 NH_4F in 0.02N HCl as extractant and measuring the extracted P calorimetrically at 660nm by the molybdenum blue method (Bray and Kurtz; 1945).

3.7.5 Potassium

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

3.7.6 Extraction of exchangeable bases (Na, Ca and K)

These cations were determined using 1N ammonium acetate pH 7.0 and measured in flame photometer. Calcium was determined using EDTA titration method of Moss (1961) while potassium was determined by the flame photometer.

3.8 Agronomic Parameter

Four plants from the central row of each plot were randomly selected, tagged and data taken on them.

3.8.1 Plant Height

Plant height was measured with a graduated pole at 60, 120, and 180 days after planting (DAP). Measurements were taken from the soil level to the terminal end of the plant.

3.8.2 Plant height at first branching

Plant height at branching was measured with a graduated pole. The measurement was taken from soil level to the height at branching.

3.8.3 Canopy Spread

Canopy development was measured by a graduated pole, taken from one direction (North-South) on each plot, across the field, 60, 120, and 180 DAP.

3.9. Yield Parameters

3.9.1. Number of roots per plant

Four plants from each plot were harvested and the number of roots per plant determined from the relation:

Number of roots per plant = Number of roots harvested / Number of plants.

3.9.2 Root Diameter

Roots harvested were selected and their diameter taken with a Venier Calipers. The mean diameter was calculated with the relation: Root diameter/ number of roots.

3.9.3. Mean Fresh Shoot Biomass

The fresh shoot of the plants were weighed and the mean weight determined as:

Mean Fresh shoot weight = Total shoot weight / Number of plants harvested

3.9.4. Mean root weight

Roots harvested were weighed and the mean weight determined by a proportion of Weight of roots to Number of roots.

Mean root weight = Weight of roots / Number of roots

3.9.5 Root Yield

Roots were harvested and root yield in tons per hectare determined.

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

Root yield (t/ha) = 10,000 x weight of roots from harvested stands / Number of stands harvested

3.9.6. Harvest Index

Roots harvested from each plot were weighed. Weight of above ground biomass and weight of the roots were recorded. Harvest Index was determined with the relation:

H.I = Economic Yield / Weight of above ground Biomass + Economic Yield

3. 10. Cost benefit analysis

The average yield of the treatments and varieties were converted to adjustable yields. Gross benefit, total variable cost, net benefit and extra benefit (all in GH¢) were determined. Factor underpinning the Variable cost included cost of transportation, application of fertilizer and weeding.

3. 11 Root Quality

3.11.1 Starch Content

The Reiman Balance which works based on specific gravity was used to determine the starch content. Five kilogram of sub-sample of roots were taken and immersed in water and the weight taken using the balance. The difference in weight is equal to the starch content. Starch was determined with the relation:

$$\text{Specific Weight} = \frac{\text{Weight in Air}}{\text{Weight in Air} - \text{Weight in Water}} - 142 \ldots$$

- Dry Matter Content = 158.3 x Specific Weight – 142
- Starch Content (%) = Dry Matter Content (%) – 4.61 (Kawano *et. al*., 1987).

3.11.2 Dry Matter Content

After determining yield data, a random sample of tubers were taken from the 4 plants harvested from the middle rows of each plot and chopped into smaller pieces. These pieces were mixed and 400 g taken and oven dried at 72°C for 72 hours (Koide *et al*., 2000). The weight after constant value was recorded and dry matter content calculated as percentage.

3.11.3 Sensory evaluation

Cooking quality, that is, the mealiness test was done by a sensory evaluation panel (experienced chop bar operators at Fumesua) and assessed on a scale of 1 to 4. *1Poor, 2-good, 3- very good, 4-excellent.* This was done after boiling the roots for approximately 45 minutes**.**

3.11.4 Data Analysis

All data was analysed using the Analysis of Variance Technique and the Genstats Statistical package. Differences among treatment means was determined using Least Significant Difference (LSD) procedure at 5% level of probability.

CHAPTER FOUR

RESULTS

4.1 Rainfall data for June, 2014 to May, 2015.

The rainfall data for the period of study is presented in Table 4.1. The lowest amount of rainfall of 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 1406.4 mm.

Table 4.1: Rainfall for June, 2014-May, 2015.

Year	**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	98.1	1382	183.6	154.8	-	-	-	-	-	-	-	574.9

4.2 Characterization of the soil and organic material used in the experiment

The results of soil physic - chemical properties in Table 4.2 showed a pH value of 6.8 indicating slightly acidic conditions. Total C, N, and P, were 0.12%, and 4.96% respectively, and exchangeable K of 0.38% Cmol/kg. The soil has a sandy loam texture.

Table 4.2: Physico – chemical properties of soil and poultry manure used in the experiment

Physical properties	Soil (0-15 cm)	PM
Organic carbon (%)	2.27	25.26
Calcium (%)	-	3.21
Total nitrogen (%)	0.12	2.35
Potassium (k) (cmol/kg)	0.38	3.13
Available Phosphorus (P) (mg/kg)	4.96	1.07
pH	6.8	7.67
Soil Texture	Sandy loam	-
Sodium (%)	-	0.22
Magnesium (%)	-	4.70

4.3 Plant Height.

Plant height results are presented in Table 4.3. Varietal differences were not significant (P>0.05) on all days of sampling. There were significant differences among the fertilizer treatments on all days of sampling. At 60 DAP, all the fertilizer treatment effects were similar, but each effect was significantly (P<0.05) higher than the control treatment effect. At both 120 and 180 DAP samplings, the poultry manure only treatment effect was significantly higher than the control treatment effect only. All other fertilizer treatment effects were statistically similar.

Table 4.3: Effects of organic and inorganic fertilizer application and Variety on Plant Height of cassava plants at 3 sampling periods

Treatment	Plant height (cm) at		
	60 DAP	**120 DAP**	**180 DAP**
Variety Sika			
	31.4	109.8	191.3
Ampong	38.2	105.5	186.5
Bankyehemaa	42.5	122.2	183.7
LSD (0.05)	**NS**	**NS**	**NS**
Fertilizer NPK			
only	35.6	110.1	206.9
Poultry manure	46.6	125.0	211.3
½ (NPK+PM)	46.7	114.7	194.1
Control	20.6	100.4	136.5
LSD (0.05)	**13.4**	**22.2**	**31.5**
CV (%)	**36.8**	**20.2**	**17.2**

4.4 Height at branching

The results for height at branching is shown in Table 4.4. There was no significant difference (P>0.05) among the fertilizer treatments. The effect of variety on height at branching showed significant difference. *Ampong* variety branched at the tallest height which was significantly higher than branching in the other varieties. Additionally, height at branching in the *Bankyehemaa* variety was significantly higher than branching in the *Sika* variety.

Table 4.4: Effects of organic and inorganic fertilizer application and variety on height at branching

Treatment	Height at Branching (cm)
Variety Sika	
	45.7
Ampong	63.7
Bankyehemaa	56.5
LSD (0.05)	**6.6**
Fertilizer NPK	
only	57.6
Poultry manure	58.0
½ (NPK+PM)	52.2
Control	53.2
LSD (0.05)	**NS**
CV (%)	**4.2**

4.5 Canopy Spread

Results of canopy spread as shown in Table 4.5 indicates that varietal differences at 60 and 120 DAP were not significant. However, at 180 DAP the canopy spread of the *Bankyehemaa* variety was greater than that of the *Ampong* variety only. Fertilizer application significantly affected cassava canopy spread. On all sampling days, the fertilizer-applied treatment effects were similar, but each effect was significantly higher than the control treatment.

Table 4.5: Effects of Fertilizer Types and Variety on Canopy Spread sampled at 3 occasions

Treatment	Canopy Spread (cm)		
	60 DAP	**120 DAP**	**180 DAP**
Variety Sika	34.7	117.9	225.2
Ampong	34.5	112.3	180.6
Bankyehemaa	42.3	109.9	228.2
LSD (0.05)	**NS**	**NS**	**47.3**
Fertilizer Types NPK only	39.1	115.2	244.0
Poultry manure	43.8	125.3	246.3
NPK+PM	41.4	140.5	232.8
Control	24.4	72.2	104.0
LSD (0.05)	**6.8**	**27.2**	**54.7**
CV (%)	**18.7**	**24.6**	**26.5**

4.6 Shoot Biomass.

Varietal differences in shoot biomass was significant, with that of the *Sika* variety being significantly higher ($P<0.05$) than that of the *Ampong* variety only (Table 4.6). Treatment effects of *Ampong* and *Bankyehemaa* varieties were not significant. Fertilizer application significantly influenced cassava shoot biomass with all the fertilizer-applied treatments producing similar biomass but either effect was significantly higher than the control treatment effect (Table 4.6), that is, no significant difference among the fertilizer used.

Table: 4.6: Effects of organic and inorganic fertilizer types and variety on Shoot Biomass

Treatment	Shoot Biomass (t/ha)
Variety Sika	55.4
Ampong	39.6
Bankyehemaa	44.3
LSD (0.05)	**15.78**
Fertilizer NPK only	44.7
Poultry manure	51.6
½ (NPK+PM)	42.8
Control	32.5

LSD (0.05)	**18.22**
CV (%)	**34.6**

4.7. Number of Roots, Roots Diameter and Mean Root Weight.

The number of roots per plant, roots diameter and mean root weight are shown in Table 4.7. Varietal differences for number of roots were not significant (P>0.05). Significant differences existed among fertilizer treatment; the number of roots from the poultry manure only treatment was the greatest, and this was significantly higher than those of the control and combined fertilizer treatments only. Additionally, the control treatment effect was significantly lower than that of the NPK only treatment.

Roots diameter was similar in the *Ampong* and *Bankyehemaa* varieties, and either varietal effect was significantly higher than the *Sika* variety effect (Table 4.7). All the fertilizer-applied treatments produced significantly greater tuber diameter than the control treatment (Table 4.7). Tuber weight did not significantly differ among the varieties at 5% probability. All the fertilized treatment effects were also similar, but each effect was significantly higher than the control treatment effect.

Table: 4.7: Effects of organic and inorganic fertilizer types and variety on number of roots per plant, roots diameter (mm) and Mean Root Weight (kg/ root)

Treatment	**Number of Roots per plant**	**Roots Diameter (mm)**	**Mean Root Weight (kg/ root)**
Variety Sika	5.10	42.61	10.35
Ampong	5.60	50.49	11.85
Bankyehemaa	6.03	49.92	11.73
LSD (0.05)	**NS**	**4.23**	**NS**
Fertilizer Types NPK only	6.03	53.99	12.66
Poultry manure	6.77	54.44	11.23
NPK+PM	5.03	53.50	13.71
Control	4.48	9.67	7.64
LSD (0.05)	**1.14**	**4.88**	**2..86**

CV (%)	**21.0**	**10.50**	**25.90**

4.8. Root Yield and Harvest Index

Results for roots yield and harvest index are presented in Table 4.8. The results of harvest index as affected by fertilizer application and variety are shown in Table 4.8. Treatment effects of *Ampong* and *Bankyehemaa* varieties were similar, but each varietal effect was significantly higher than that of Sika variety. Fertilizer application did not significantly (P>0.05) affect harvest index

Cassava root yield was not significantly different among the varieties used (Table 4. 8). Fertilizer application, however, had significant effect on tuber yield. All the fertilized treatments produced root yield that was significantly higher than the control treatment effect.

Table 4.8: Effects of organic and inorganic fertilizer types and variety on Root Yield (t/ha) and Harvest Index.

Treatment	**Root Yield (t/ha)**	**Harvest Index**
Variety Sika	**25.90**	**0.37**
Ampong	**29.60**	**0.46**
Bankyehemaa	**29.30**	**0.43**
LSD (0.05)	**NS**	**0.095**
Fertilizer Types NPK only	**31.70**	**0.44**
Poultry manure	**28.10**	**0.36**
½(NPK+PM)	**34.30**	**0.43**
Control	**19.10**	**0.43**
LSD (0.05)	**7.10**	**NS**
CV (%)	**25.90**	**14.20**

4.9. Root Dry Matter and Starch Content.

Dry matter yield from the *Bankyehemaa* variety was greatest and this was significantly greater than those from *Sika* and *Ampong* varieties (Table 4.9). The difference in the latter two varieties was not significant (P>0.05). Fertilizer application, however, did not significantly affect dry matter content of the varieties.

Treatment effect on cassava starch content are presented in Table 4.9. *Bankyehemaa* variety recorded the greatest starch content, which was significantly higher (P<0.05) than those of the other varieties. Varietal difference between *Sika* and *Ampong* was not significant. Fertilizer application did not have a significant effect on starch content of the varieties studied.

Table 4.9: Effects of organic and inorganic fertilizer types and variety on Root dry matter and starch content

Treatment	Dry matter content (%)	Starch content (%)
Variety Sika		
	33.79	29.20
Ampong	33.54	28.93
Bankyehemaa	36.08	31.48
LSD (0.05)	**1.14**	**1.13**
Fertilizer Types		
NPK only	33.79	29.17
Poultry manure	34.93	30.33
½ (NPK+PM)	35.09	30.49
Control	34.05	29.48
LSD (0.05)	**NS**	**NS**
CV (%)	**3.90**	**4.50**

4.10 Root Cooking Quality

The results of the cooking quality as affected by the treatments are presented in Table 4.10. Varietal differences were not significant at 5% level of probability; however, fertilizer treatments showed significant differences. Poultry manure only treatment was significantly higher than the control treatment effect only. Other treatment effects were similar.

Table 4.10: Effects of organic and inorganic fertilizer types and Variety on Root Cooking Quality

Treatment	Tuber cooking quality
Variety Sika	**2.00**
Ampong	**2.20**
Bankyehemaa	**2.50**
LSD (0.05)	**NS**
Fertilizer Types NPK only	**2.22**
Poultry manure	**3.40**
½ (NPK+PM)	**2.56**
Control	**1.60**
LSD (0.05)	**1.01**
CV (%)	**34.50**

1= poor. 2=good. 3= very good. 4= Excellent

4.11: Cost Benefit Analysis

Results on cost benefit analysis of the use organic and inorganic fertilizer and their combinations are presented in appendix 1.0. The use of fertilizer resulted in an extra benefit over the control with *Bankyehemmaa* and ½(NPK+ PM) producing the highest extra benefit of GH¢ 5725.6./ha. All fertilizer treatments produced marginal benefits ranging from 1.24 (*Sika*) to 11.35 (*Bankyehemaa*).

CHAPTER FIVE

DISCUSSION

5.1. Treatment Effect on growth of cassava

Plant height results as presented in Table 4.3 showed significant differences among the fertilizer treatments on all the days of sampling; however, varietal differences were not. Plants treated with poultry manure recorded the highest plant height, but all fertilizer treatments were higher than the control treatment. Poultry manure apart from providing nutrients to the plants, also improve the soil structure by adding organic matter, conserve water and reduce the loss of water and nutrients to plants. The increase in plant height is due to increase in cell elongation of plant tissues as a result of steady release and mineralization of nutrients from poultry manure (Sharma and Govil, 1988; Christopher *et al*., 2007). In a similar study, Adoa (2009) reported of the greatest plant height with the application of poultry manure on *Nkabom* and IFAD varieties.

There was no significant difference among the fertilizer treatments on the height at branching as shown in Table 4.4. The effect of variety on height at branching showed significant difference. The *Ampong* variety branched at the tallest height which was significantly higher than branching in the other varieties. Additionally, height at branching in the *Bankyehemaa* variety was significantly higher than branching in the Sika variety. Early branching and increase in number of branches per plant is important to expose the leaves to sunlight for photosynthesis and increased translocation for higher photosynthate accumulation (Okogun *et al*., 1999). Increased branching can also be an effective means of suppressing weeds.

Maximum growth rates of leaves, flowers, stems, canopy size, branching habit and dry matter partition to leaves and stems were accomplished between 90-180 DAP (Tavora *et al*., 1995), which is the most active vegetative growth for cassava according to Ramanujam and Indira (1987). This is shown in Table 4.5 where results of canopy spread indicated that varietal differences at 60 and 120 DAP were not significant. However, at 180 DAP, the canopy spread of the *Bankyehemaa* variety was greater (228.2cm) than that of the *Ampong* (180.6cm) variety only. Fertilizer application significantly affected cassava canopy spread. On all sampling days, the fertilizer-applied treatment effects were similar, but each effect was significantly higher than the control treatment.

The results of canopy spread showing the poultry manure treatment recording the greatest effect is probably from its supply of organic matter and nutrients which improved soil structure and aggregate stability, and enhanced water holding and cation exchange capacity, and supply a wide range of nutrients, including secondary and micro-nutrients. Fertilizer application increases soil physical properties, and organic carbon content apart from supplying nutrients (Ayoola and Adeniyan, 2006). Fertilizer application both Organic and inorganic promoted growth of stems and leaves, increased the chlorophyll content and the photosynthesis of leaves and improved the physiological metabolism of cassava (Lou *et al*., 2008; Shafeek *et al*., 2012).

The period of maximum rate of dry matter partitioning depends on genotype-byenvironmental condition interaction (Fregene *et. al.*, 1994). Canopy spread above 90 cm reflects full canopy closure, as a result of 1m x 1m planting distance and the spread in cassava ensures greater interception of solar radiation for photosynthesis

(Lebot, 2009). Tolessa and Friensen (2001) reported that at 120 DAP, the leaves are able to intercept most of the radiation falling on the canopy and it is the time when the maximum size of the canopy with the maximum dry matter partition of the leaves and stems are obtained. Howler (1990) earlier stated that large bulk of foliage are created by the action of nitrogen and consequently an extensive assimilating area, a prerequisite for the good development of the roots.

5.2. Treatment Effects on Root Yield and its Components

Varietal differences in shoot biomass was significant, with that of the *Sika* variety being significantly higher (55.4 t/ha) than that of the *Ampong* variety only (39.6 t/ha) as shown in Table 4.6. This may be due to varietal differences. Fertilizer application significantly influenced cassava shoot biomass with all the fertilizer-applied treatments producing similar biomass but each effect was significantly higher than the control treatment effect. The application of PM produced the highest fresh shoot biomass (51.6 t/ha) and control treatment produced the lowest value of 32.5t/ha All fertilizer treatments produced higher shoot biomass than the control. Availability of nutrients certainly led to greater growth and hence greater shoot biomass than in the control treatment. This indicates that for cassava growth soil nutrient amendment cannot be overlooked by farmers.

Varietal differences for number of roots were not significant; however, significant differences existed among fertilizer treatment. The number of roots from the poultry manure only treatment was the greatest (6.8), and this was significantly higher than other treatment effects (Table 4.7). The trend in number of roots per plant is attributed to the observation that manure promotes the photosynthetic organs in the plant to produce and make available more assimilates to the root and increase the yield of cassava (Zhongyong *et al.*, 2006). The number of storage roots determines sink capacity. In a study to investigate yield performance of five cassava genotypes under different fertilizer rates, Parkes *et al*. (2012) observed that number of roots per plant was not significantly influenced by the genotype but all rates of fertilizer applied treatments significantly outnumbered the control. An increase in the number of storage roots per plant in response to organic fertilizer application has also been observed by Kasele (1980) and Pellet and El-Sharkawy (1997).

Ampong and *Bankyehemaa* varieties showed similar roots diameter and either varietal effect was significantly higher than the Sika varietal effect (Table 4.7). All the fertilizer treatments produced significantly greater roots diameter than the control treatment (Table 4.7). PM gave the highest value (54.44mm) and the lowest (9.67mm) from the control. Leo and Kabambe (2014) observed in a similar experiment that the significant increase in number of roots per plant, and roots diameter has a positive correlation with fertilizer treatment. They further observed that, an increased roots diameter and length is important for the markets. Amanullah *et al*. (2006) observed that greater tuber yield following the application of organic fertilizer is attributed to favorable changes in soil, such as loose and friable soil condition enabling better root formation, as well as slow and steady availability of nutrients throughout the crop growth period.

Roots weight and yield did not significantly differ among the varieties. On the other hand, all the fertilized treatment effects were also similar, but each effect was significantly higher than the control treatment effect. The control recorded lowest mean root weight and root yield. The combined application recorded the highest mean root weight 13.71kg/root and root yield of 34.30 t/ha. Poultry manure only treatment effect was significantly higher than the control. Adjei-Nsiah and Issaka (2013) observed that average fresh tuber yield increase from 13.7 t/ha without amendment to 23.7 t/ha with application of 4 t/ha poultry manure. Fertilizer application resulted in greater root yields than the control treatment. This observation supports the findings of many researchers (Wilson and Dufour, 2002; Agbaje and Akinlosotu, 2004; Issaka *et al*., 2007; Ojeniyi *et al*., (2012), who recorded higher root yield when fertilizer was applied.

The combined fertilizer use is known to increase synchrony and reduce losses by converting inorganic N into organic forms (Kramer *et al*., 2002). It also reduces the environmental problems that may arise from the use of sole inorganic fertilizers and improves the microbial properties of the soil (Belay *et al*., 2001). The use of mineral fertilizer in combination with poultry manure has shown to increase yield as much as 60 t/ha of cassava roots (CSIR- AGRA, 2012). Variation in the yields could be attributed to the efficiency of partitioning of dry matter to the sinks. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Tisdale *et al*., 1993).

The results on harvest index as affected by fertilizer application and variety are shown in Table 4.8. Treatment effects of *Ampong* and *Bankyehemaa* varieties were similar, (0.46) and (0.43) respectively; but each varietal effect was significantly higher than that of Sika variety (0.37). The indices in the present study were in the range of these obtained by Peressin *et al*. (1998), who observed harvest index values of 0.49-0.77 after 10-12 months after planting. The distribution of dry matter to the economically useful plant parts is measured by harvest index which represents the efficiency of storage root production (Alves, 1998). Significant differences in harvest index have been reported among cultivars, indicating that it can be used as a selection criterion for higher yield potential in cassava (Tavora *et al*., 1995).

Fertilizer application did not significantly affect harvest index.

5.3. Roots Quality (Dry Matter and Starch Content)

Dry matter yield from the *Bankyehemaa* variety was the greatest, recording (36.08%) and this was significantly higher than those from *Sika* (33.79) and *Ampong* (33.54%) varieties (Table 4.9). The difference in the latter two varieties was not significant. The accumulation of assimilate is a major determining factor of dry matter content to the sink from the source and increases with age. Farmers over the years have been using dry matter as an index for cultivating particular varieties that suit their food needs for *fufu*, *ampesi* and others (Adoa, 2009). The importance attached to dry matter content by farmers is by their own conviction and effects or through breeding programmes. Farmers are therefore able to select high dry matter varieties for cultivation through experience over the years.

Influence of source size on dry matter production shows that the storage root growth rate is reduced when the source size is increased from leaf area index 3.0 to 6.0 (Ghosh *et al*., 1988). Adoa (2009) reported of a strong positive correlation between dry matter content and starch content. Safo-Kantanka and Asare (1993) reported that tuber dry matter could only explain 40% of variation in starch yield in cassava. Starch quality, is dependent on the solubility, swelling power and water binding capacity (Baafi, 2005). The Bankyehemaa variety recorded the greatest starch content (31.48%) which was significantly higher than the other varieties Sika (29.20%) and Ampong (28.93%) as shown in Table 4.9. Fertilizer application, however, did not significantly affect dry matter and starch content of the varieties, despite others observation (Parkes *et al*., 2012).

5.4. Cooking Quality

Varietal differences were not significant at 5% level of probability; however, there was significant effect among fertilizer treatment. Significant difference in poultry manure treatment only was recorded, scoring *very good* in cooking qualities.

Difference between poultry manure and ½(NPK+PM) treatment was not significant. Adoa (2009) made a similar observation where poultry manure treatment enhanced the cooking quality of cassava. The results suggest positive relationship between dry matter and cooking quality, thus the higher the dry matter, the better the cooking quality (mealiness). This result agrees with the observation that there is positive correlation between dry matter content and cooking quality of cassava (Safo-Kantanka and Asare, 1993; Safo-Kantanka and Owusu - Nipa, 1992)

5.5. Cost Benefit Analysis of the Use of fertilizer over Control

Results on cost benefit analysis of the use of organic and inorganic fertilizer and their combinations are presented in appendix 1. The use of fertilizers resulted in an extra benefit over the control.

Extra financial benefit ranges from GH¢ 851.2 t/ha to GH¢ 5725.6 t/ha. Fertilizer investment in *Sika Bankye* production gave an extra benefit of GH¢ 1945.6 t/ha with the application of ½(NPK+PM). *Ampong* gave an extra benefit of GH¢ 5165.6 t/ha with the application of ½(NPK+PM). *Bankyehemaa* gave the highest financial extra benefit reward, thus GH¢ 5725.6 t/ha with the application of ½(NPK+PM).

All fertilizer treatments produced marginal benefits ranging from 1.24 (*Sika*) to 11.35 (*Bankyehemaa*) which showed greater profit in the use of fertilizer over control. Marginal benefits which were greater than one suggest that the farmer gets the same value in terms of profit. In a tentative cost to establish one hectare of cassava farm, total production cost was estimated to be 209,950 Naira, while total income was 412,500 Naira, giving a profit margin of 202,550 Naira, with fertilizer cost estimated as 30400 Naira (Smallholder Foundation, 2013).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The following conclusions can be made from the results obtained in this study. For maximum growth and tuber yield of cassava some, form of soil amendment whether organic or inorganic fertilizer must be applied in most soils. However, the combined application of organic and inorganic fertilizers produced the greatest root weight and tuber yield under the conditions of this study.

Contrary to the perception of some farmers, all root quality factors- dry matter yield, starch content and cooking quality- were not affected by fertilizer application. Indeed, cooking quality was improved by the application of poultry manure and fertilizer.

Finally the use of fertilizers, both organic and inorganic was more profitable than when no fertilizer was applied.

6.2 Recommendation

Since fertilizer application was more profitable than the no fertilizer (control), farmers should be encouraged to apply fertilizer in cassava cultivation. This means fertilizers must be made affordable and available to them. Future research must aim at studying various rates to obtain the highest yield. In addition, time of application and monitoring nutrient losses following fertilizer application must be studied to ensure sustainable production.

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APPENDICE

APPENDIX 1.0 Cost Benefit Analysis Sheet of the Use of fertilizer over Control

Variety	**SIKA**				**AMPONG**				**BANKYEHEMAA**			
fertilizer type	Cont.	NPK	PM	½ (NPK+PM)	Cont.	NPK	PM	½ (NPK+PM)	Cont.	N-P204K2O	PM	½ (NPK+PM)
Average Yields (t/ha)	21,0	25.9	27.9	28.8	17.8	38.9	26.1	35.8	18.5	30.3	30.3	38.3
Adjustable Yield (t/ha)	18.9	23.3	25.1	25.9	16.0	35.0	23.5	32.2	16.7	27.3	27.3	34.5
Gross Benefit, GH/ha	6615	8155	8785	9065	5600	12250	8225	11270	5045	9555	9555	12075
Total Variable Cost (GH/ha)	1225	1913.8	1545	1729.4	1225	1913.8	1545	1729.4	1225	1913.8	1545	1729.4
Net Benefit (GH/ha)	5390	6241.2	7240	7335.6	4375	10336.2	6680	9540.6	4620	7641.2	8010	10345.6
Extra Benefit		851.2	1850	1945.6		5961.2	2305	5165.6		3021.2	3390	5725.6
Marginal Analysis		1.24	5.78	3.86		8.65	7.20	10.24		4.39	10.59	11.35
%		124	578	386		865	720	1024		439	1059	1135

Appendix 5.6.1. Cost Benefit Analysis Sheet of the Use of fertilizer over Control

Variety	**SIKA**				**AMPONG**				**BANKYEHEMAA**			
fertilizer type	Cont.	NPK	PM	½ (NPK+PM)	Cont.	NPK	PM	½ (NPK+PM)	Cont.	N-P204-K2O	PM	½ (NPK+PM)
Average Yields (t/ha)	21,0	25.9	27.9	28.8	17.8	38.9	26.1	35.8	18.5	30.3	30.3	38.3
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Net Benefit (GH/ha)	5390	6241.2	7240	7335.6	4375	10336.2	6680	9540.6	4620	7641.2	8010	10345.6
Extra Benefit		851.2	1850	1945.6		5961.2	2305	5165.6		3021.2	3390	5725.6
Marginal Analysis		1.24	5.78	3.86		8.65	7.20	10.24		4.39	10.59	11.35
%		124	578	386		865	720	1024		439	1059	1135