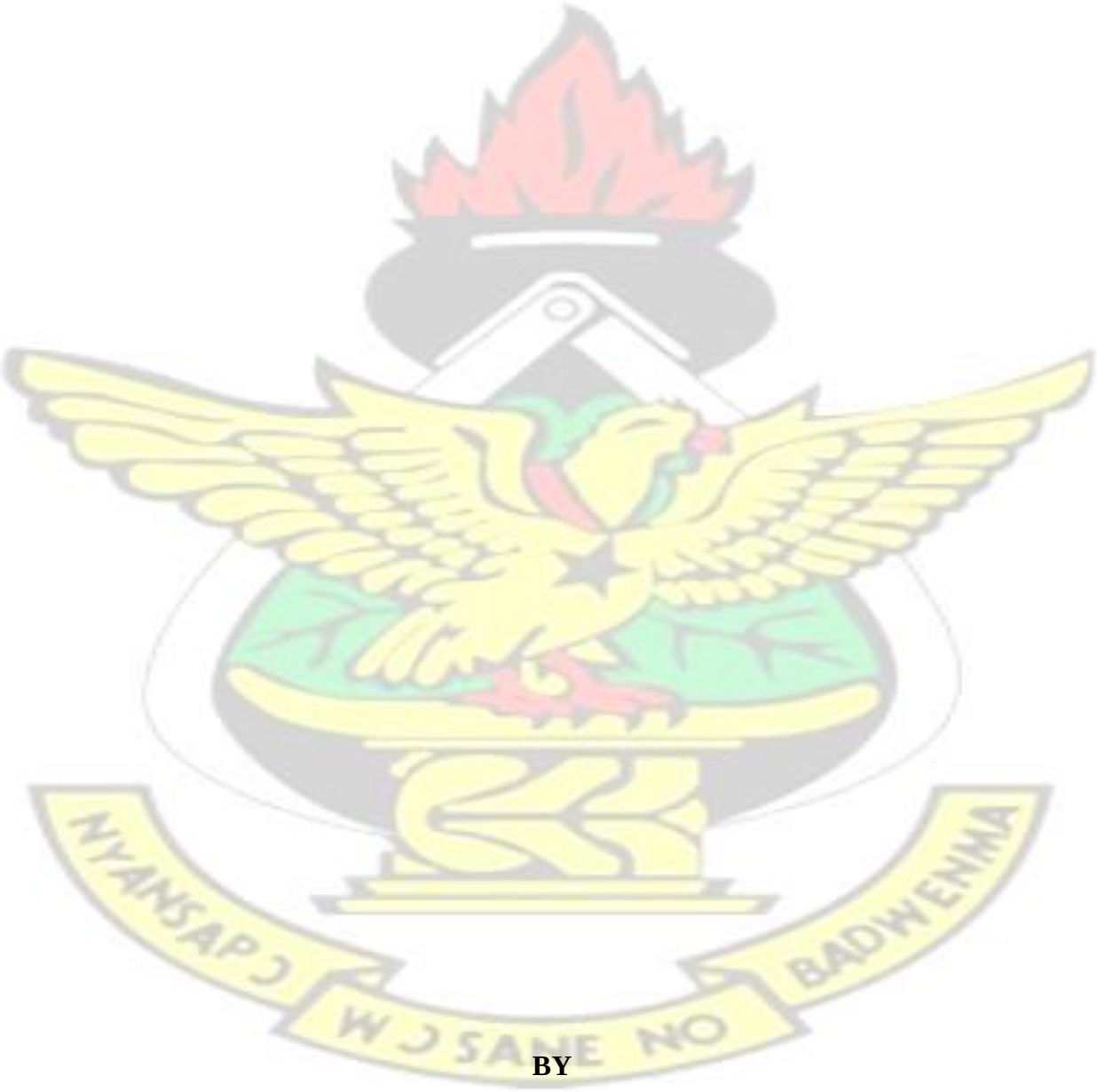
# EVALUATION OF GROWTH, YIELD AND ROOT QUALITY OF FOUR (4) CASSAVA (*Manihot esculenta Crantz)* VARIETIES IN THE SEMI-DECIDUOUS ZONE OF GHANA






**BY**

**GIFTY BAFFOUR GYAU JNR**

**JUNE, 2015**

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,**

**KUMASI, GHANA**



**SCHOOL OF GRADUATE STUDIES**

**DEPARTMENT OF CROP AND SOIL SCIENCES**

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**BSc. AGRICULTURE (HONS)**

**A Thesis Submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture,**

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**In partial Fulfilment of the Requirement for the Degree**

**Of**

**Master of Philosophy in Agronomy (Crop physiology)**

**JUNE, 2015**

## CERTIFICATION

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.

| | | |
|---|---|---|
| Gifty Baffour Gyau Jnr. | …… | ……. |
| (Student) | Signature | Date |

Certified by:

| | | |
|---|---|---|
| Dr. Eric Asare | …… | …… |
| (Supervisor-Late) | Signature | Date |
| Dr. Charles Kwoseh | ……. | …….. |
| (Head of Department) | Signature | Date |

**ABSTRACT**

Evaluation of crops is crucial to select superior varieties for a targeted region. A field experiment was conducted at the CSIR-Crops Research Institute of Ghana (CRI) experimental field within the semi-deciduous zone of Ghana from April 2013- April 2014 to evaluate the growth, yield and root quality of four cassava (*Manihot esculenta crantz)* varieties. The varieties (treatments) were; Ampong, Agbelifia, Doku (all improved varieties) and Debor (local) variety. The experiment was a randomized complete block design with four (4) replications. All agronomic/ field management practices were carried out when necessary. The growth parameters measured were plant height, number of branches, length/ height at branching and the stem diameter. Top weight and the total crop biomass were also taken at harvest. Results indicated that, plant height showed significant differences ($P<0.05$) among the varieties at 3, 4, 5, 6, 10 and 11 months after planting. Number of branches per plant also showed no significant difference ($P>0.05$). Length of branching showed significant differences among the varieties during 8 months after planting ($P<0.05$). Varietal differences were highly significant for the height at branching across all the sampling period ($P<0.001$). Yield components measured were; number of roots, average number of roots per plant, number of stands, root weight, root length, root diameter. Most of the yield components were not significantly different from each other. But, root length and diameter showed significant differences among the varieties ($P< 0.05$).

Quality of the root was also evaluated based on the cooking and starch content. Cooking quality showed highly significant differences among the varieties ($P< 0.001$).

The, response of the varieties to external factors within the agro-ecological environment was also measured and such parameters measured were; light interception, soil moisture, temperature (canopy, leaf and soil), relative humidity, diseases as well as other leaf response variables; stomatal

conductance and the leaf chlorophyll content. Varieties were significantly different from each other ($P< 0.05$) for temperature (canopy, soil and leaf), soil moisture, humidity, diseases and the leaf chlorophyll content.



The over-all result obtained indicates that; in most of the growth parameters measured, the improved varieties showed greater responses in terms of number of roots, root yield, dry matter and harvest index than the local the variety. This conforms that the improved varieties are superior in performance and have been developed and selected for special purposes than the local.

In terms of cooking and starch quality, the local variety, Debor was however, the best.

## DEDICATION

I dedicate this work to Dr. Joseph Sarkodie- Addo at the Department of Crops and Soil Sciences (KNUST) and my Supervisor Dr. Eric. Asare (late).

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My sincere gratitude goes to the Almighty God who has seen me through all these years of schooling. I wish to express my sincerest thanks to my parents, Mr. Kofi Baffour Gyau and Mrs. Vida Baffour Gyau for their good upbringing and support they have given me throughout my life and especially during my Master's degree programme. I would like to express my appreciation to my lovely twin sister, Gifty Baffour Gyau Snr. of the Department of Environment and Landscape Management – Cranfield University (London) who has been of immense support throughout my education. I am highly indebted to my supervisors Dr. Joseph Manu- Aduening (CSIR-CRI); Dr. Eric Asare (late), of the Department of Crop and Soil Sciences for their suggestions, criticisms and corrections.

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Table of Contents

**LIST OF TABLES**

**TABLE** Page

## LIST OF PLATES

**PLATES** **PAGE**

## LIST OF ABBREVIATIONS

| | |
|---|---|
| % | Percentage |
| ACMVD | African Cassava Mosaic Virus Disease |
| AGDP | Agricultural Gross Domestic Product |
| Bio | Biomass |

| | |
|---|---|
| CBB | Cassava Bacterial Blight |
| CAD | Cassava Anthracnose Disease |
| Cm | Centimetres |
| CRI | Crops Research Institute of Ghana |
| CSIR | Council for Scientific and Industrial Research |
| Diam | Diameter |
| FAO | Food and Agriculture Organization |
| FAOSTAT | Food and Agriculture Organization Statistics |
| g | Grams |
| IITA | International Institute for Tropical Agriculture |
| Kg | Kilogram |
| Lsd | Least significant difference |
| M W | Molecular weight m/s Meters per Seconds |
| MAP | Months after planting |
| MoFA | Ministry of Food and Agriculture |
| $^{o}C$ | Degree Celsius |
| OC | Organic carbon |

| | |
|---|---|
| P-value | Probability value |
| RCBD | Randomized Complete block design |
| t/ha | Tonnes per Hectare |

# CHAPTER ONE

## 1.0 INTRODUCTION

Cassava, *Manihot esculenta crantz*, was introduced into Africa by the Portuguese from Latin America in the 16th century (Nweke *et al.*,1994) and is the third most important source of calories in the tropics and the second most important food crop after maize in terms of global annual production (FAOSTAT, 2010). Cassava is by far the largest agricultural commodity produced in Ghana and represents 22 percent of Agricultural Gross Domestic Product (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 (MOFA, 2009). MOFA (2010) reported that, cassava is an important starchy staple crop in Ghana with per capita consumption of about 153 kg/year. In terms of quantity produced, cassava is the most important root crop followed by yam and cocoyam, but ranks next to maize in terms of area cultivated. Cassava today covers about 21.68% of the total area of land grown to food crops. The area cropped to cassava has increased from an average of 577,100 ha in 1997 to 889,364 ha in 2011(MOFA, 2009).

It can grow on poor soils, is easily propagated, requires little cultivation and can tolerate periodic and extended periods of drought (Hillocks *et al.,* 2003). Most cassava produced is consumed in the form of ‘’fufu’’ but there are small farmers currently in Ghana that process cassava into diverse foods (ManuAduening *et al.,* 2006). Traditionally, farmers also cultivate cassava in plots far away from the homestead that are relatively infertile. The soils closer to the homesteads which are intensively used for cultivating are low in soil organic matter (Adjei, 2006). In the forest/savanna transitional agroecological zone where the bulk of cassava is produced, cassava is ranked as the most important staple food (Asafu-Agyei *et al.,* 1998) and has multiple uses. It is a source of income for most rural dwellers where it is

processed into gari, starch, and animal feed or cassava chips. The products are used for the production of industrial alcohol, cosmetics, and pharmaceuticals and in the textile industry (IITA, 1990). This makes it an important commodity to be transported to neighboring countries including Mali, Niger and Burkina Faso. Cassava cropping is also used to regenerate degraded soils (Adjei, 2012) as in some parts of East Africa (Fermont, 2009) and in Benin (Saidou, 2004). In West Africa for instance, cassava has become a very popular crop and is fast replacing yam and other traditional staples gaining grounds increasingly as an insurance crop as against hunger (Balogoplan, 2004). The main food product which is the tuberous roots can be harvested from the soil up to three years after maturity (Lebot, 2009). This provides an important form of insurance against social disruption, prolonged droughts, or other periods of stress and unrest. The nutritional value of the storage root is mainly caloric even though it contains a lot of water, fibre, ash and protein (Marcelis and Heuvelink 2002). The leaves contain about 30% proteins by dry weight and are eaten in some parts of Africa as vegetable (Burns *et al*; 2010).

While it is already a major staple crop, it has the potential to be an important part of the solution to improving food security in times of climate change and hunger (El-Sharkawy, 2003), thus epitomized in several local languages as food for the poor (Adjei *et al;* 2007). However, major limitations associated with cassava production industry in Africa and for that matter Ghana are; low yielding (MOFA, 2005), poor quality in terms of cooking and starch, diseases and pests (Baiyeri *et al*., 2008a), erratic and unpredictable climatic conditions (Ekanayake, 1998a) often high/low drought conditions (Salam, 2009). In order to meet the ever- growing demands of people in Ghana through increasing the yield potential and quality of the crop, more improved varieties of cassava have been released (McCarl, 2007). The characteristics of these improved varieties are that; whilst some are high yielding others are also tolerant to diseases and pests and early maturing. These varieties have therefore been extensively used by farmers throughout the country (Dankyi *et al*; 1994) for various purposes.

In spite of these, yields of cassava are low and far below the crops achievable yields. MOFA (2005) reported that, cassava has the potential to yield up to 30mt/ha but yields are far below average; yielding up to 12mt/ha, resulting in a wide gap between what is currently produced and what is actually needed (MOFA, 2009). But yield potential in cassava cultivation is an outcome of several processes at all stages in the growth and development of the crop and the primary goal of any yield assessment is usually to identify superior cultivars for a targeted region (Yan *et al.*, 2001) since, the actual yield and the consistency of yield (Duane, 2003); of any adapted cultivar is its ultimate index of adaptation (Cooper and Byth, 1996).

Therefore, as a way of improving the level of production and quality of cassava, evaluations of the crop are often needed to ensure that selections made have a reliable and a predictable performance in the farmer's field.

The general objectives of the research were; to evaluate the differences in growth, yield and the root quality (cooking and starch) of the four cassava varieties and the specific objectives were also to;

- To determine the response of the varieties to some external factors such as light interception, soil moisture and humidity within the agro-ecological environment.
- To determine the best yielding variety in the semi-deciduous zone of Ghana
- To select the promising variety for further research

# CHAPTER TWO

## 2.0 LITERATURE REVIEW



### 2.1 Origin of the crop

Cassava appears to have originated in Brazil and Paraguay, but has spread throughout tropical areas of the South and Central America long before the arrival of Columbus (Mim *et al*; 2003). It is now one of the most important food crops in tropical countries throughout the world. It ranks as the 6th most important food crop worldwide, even though in western countries it is little known (Aminu, 2000). In mythology it is portrayed as a savior that protects against starvation. One school of thought suggested that, wild populations of *M. esculenta* in west-central subspecies *flabellifolia*, shown to be the progenitor of domesticated cassava, are centered in Brazil, where it was likely first domesticated more than 10,000 years (Olsen and Schaal 1999). By 6,600 BC, manioc pollen appeared in the Gulf of Mexico lowlands, at the San Andrés archaeological site. Pope *et al.*,(2001) reported that, the oldest direct evidence of cassava cultivation comes from 1,400-year-old Maya site, Joya de Cerén, in El Salvador (University of Colorado, 2007) and the species *Manihot esculenta* likely originated further south in Brazil, Paraguay and Argentina. With its high food potential, it has become a staple food of the native populations of northern South America, southern Mesoamerica, and the Caribbean by the time of the Spanish conquest (Mimura, 2007). Its cultivation was continued by the colonial Portuguese and Spanish. Forms of the modern domesticated species can be found growing in the wild in the south of Brazil. While several *Manihot* species are wild, all varieties of *M. esculenta* are cultigens (Mishra and Singhal 1992). Cassava was a staple food for pre-Columbian people in the America's and is often portrayed in indigenous art (Berrin *et al*; 2010) since being introduced by Portuguese traders from Brazil in the 16th century, maize

and cassava have replaced traditional African crops as the continent's most important staple food crops (FAO, 2000).



**2.2 Botany of the crop**

*Manihot esculenta* is a shruby perennial species that produces storage roots (Hillocks *et al*; 2000). The roots form large starchy tubers, somewhat similar to sweet potato, with a dark brown fibrous covering and white flesh (MOFA, 2001). A large, 3-4 m high, tropical woody shrubs with enlarged tuberous stems are either non-branching (slender and up to 4.5 m tall) or branched (from intermediate to highly branching patterns of no more than 1.5 m in height). Stems of the species are woody, usually with large pith and therefore brittle. The fully developed vegetative leaves have five to nine lobes, but the leaves found in association with the inflorescence are almost invariably reduced in number of lobes (most frequently three lobed but with occasional occurrences of an undivided simple leaf (Rogers, 1965). The leaves are deeply indented, palmate 3 - 7 lobed, attached to a slender stem by long petioles. It tends to branch irregularly and bears its large (20 cm long) lobed leaves near the tips of long branches. The leaves are short-lived (1-3 months) and are readily lost during drought or after insect attack. Cassava has few large basal pistillate and numerous smaller apical staminate flowers borne on the same inflorescence (Rogers, 1965). The flowers are small, based on the flowering habit.

*Manihot esculenta* is pollinated by insects (Rogers, 1965) but prolific production of readily disseminated pollen grains suggests that, wind may be an important pollinating agent (Bueno, 1987).

Profuse secretion of nectar attracts several insects, specifically bees, which are pollen disseminators. Although cassava is regarded as an allogamous species, considerable selfing may occur, especially in profusely flowering genotypes (Kawano *et al*., 1987). The fruit is a dehiscent capsule with three locules

(MOFA, 2001). Each locule contains a single carunculate seed. Most of the cultivars bear a relatively small number of fruits per plant as contrasted with the wild species (Rogers, 1965; Pujol *et al.*, 2005).

### 2.3 Climatic and Soil Conditions

Cassava is one of the most adaptable plants. It is very hardy and tolerant to a wide range of soils. It grows well in tropical humid conditions but can also withstand droughts. It does well in poor soil. It requires little care and protects itself against predators by means of poisonous latex, which is particularly evident in the leaves (Pujol *et al;* 2005). It is an ideal food crop for tropical growing conditions (Morres, 2008). Preferably, grown on light to medium soils, well-drained, pH 4.5-7 (Howeler, 1980). The crop is adapted to semi-arid conditions; it needs adequate soil moisture mainly during planting; once sprouted, it can withstand some months of drought; generally, it is not irrigated, but in some areas responds significantly to irrigation. Cassava is well adapted to very acid soils with high levels of exchangeable Al. The plant is also well adapted to low levels of available P, but requires fairly high levels of K, especially when grown for many years on the same plot. The crop is susceptible to Zinc (Zn) deficiency and often shows Zn deficiency symptoms at early stages of growth (Nasaar and Ortiz 2007). Cassava is also subjected to highly varying temperatures, photoperiods, solar radiation and rainfall.

### 2.4 Characterization of the crop

Pigmentation of the stems provides one of the most stable characteristics for differentiation of cultivars (Adugna and Labuschagne 2002). One group of cultivars has light grey stems with a silvery aspect, due in part to the granular, waxy surface, whereas another group has varying amounts of anthocyanins, causing the stems to be yellow, orange, or brown (Occiaso, 1980). An early branching genotype may start flowering as early as three months after planting while non-branching types do not flower (Hahn *et al*., 1973; Conceicao, 1979).

## 2.5 Reproductive Biology

### 2.5.1 Flowering Characteristics

Cassava varieties are classified as no flowering, poor flowering, moderate flowering, profuse flowering with poor fruit setting and profuse flowering with high fruit setting (Aesidasha and Idana 2008; Injura, 2004). The cassava plant bears separate male and female flowers on the same plant, making it monecious. The time from planting to flowering depends on the specific genotype and environmental conditions, and may vary from 1 to more than 24 months (Byrne, 1984). Male and female flowers are borne on a single branched panicle, with female flowers at the base, and male flowers toward the tip (Alfredo and Setter, 2000). The flowers are small, with the male flower being about 0.5 cm in diameter, and the female flower slightly larger. Male and female flowers are shown in flowers usually begin to open around mid-day, and remain open for about one day (Ceballos *et al.*,
2002). On a given branch, female flowers open first and the flowering is also dependent on plant habit. A flower bud typically forms when the plant branches, so that more highly branched genotypes are more prolific than those with a sparsely-branched habit. Farmers generally prefer the non-branching cassava type because it facilitates cultivation practices. Therefore, many modern cultivars fail to flower under normal growing conditions (Oosterveld and Nicholaichuk 1983). Flower bud formation is preceded by apical branching, which is a prominent visual indication of incipient flowering, and may be used to identify plants in the pre-flowering stage. Male flowers follow 1 or 2 weeks later, a characteristic called protogyny. By the time male flowers open, the female flowers on the same branch have either been fertilized or have aborted. However, because flowering on a single plant may last for more than two months, both self- and sib-fertilization may occur, with the proportion of each dependent on the genotype, the environment, and the presence of pollinating insects (Parry *et al*; 2007). Flowering may be strongly influenced by environmental factors (Palmer, 1989). A particular clone may produce no

flowers in one environment or may produce only aborted flowers or even fail to produce viable seed in another environment, and yet flower profusely and set seed in a third environment. For breeding purposes, clones are classified into different growing zones (environments, ecotypes), so that breeders may take account of the flowering habits of the plants they wish to cross (Ceballos *et al*., 2002).

### 2.5.2 Pollen

The pollen grains of cassava are quite large in size and sticky, and wind pollination appears to be of little consequence. Several species of wasp (mainly *Polistes spp* and honeybees are the main pollinators in Colombia and Africa, respectively (Kawano *et al;* 1987). Cassava pollen shows size dimorphism, the larger grains being 130 to 150 microns in diameter, whereas the smaller grains range from 90 to 110 microns (Plazas, 1991). In some varieties, the larger grains are more abundant and have better germination percentages (60%) under in vitro conditions than the smaller ones. In other cultivars, the smaller grains are more common (Pearce, 2007). Smaller grains typically germinate less efficiently than larger ones, and may have less than 20% viability. Cassava pollen loses viability rapidly after it is shed. Leyton (1993) found 97% seed set with newly-collected pollen, 56% seed set with pollen stored for 24 hours, and 0.9% seed set (one seed from 102 pollinations) after 48 hours of storage.

### 2.5.3 Seed Characteristics

Fertilized seed is viable two months after pollination, and fruit becomes mature about one month after that, or about three months after pollination (Ceballos *et al*., 2002). The fruit and seeds are ovoidellipsoidal, approximately 100 mm long and 4 to 6 mm thick (Alves, 2002). Fruits dehisce in drying and the seed initially falls close to the mother plant, but then may be further dispersed by ants, which carry an unknown percentage of the seed to their nests in the soil. Through these two mechanisms of

autochory followed by myrmecochory. A seed may be dispersed up to several meters from its place of origin (Elias and Mckey, 2000). Seed production and viability are variable, depending largely on the quality of the female parent (Kawano, 2003). Jennings (1963) reports that one viable seed per fruit and two viable seeds are obtained from each hand-pollination. Newly harvested seeds are dormant, requiring 3 to 6 months of storage before they will germinate (Andrade and Abbate 2005).

Cassava seeds are adapted to ant-dispersal, with large energy reserves that allow deep burial and a long dormancy period (Pujol *et al*., 2002). Seeds can remain viable for up to 1 year, although germination percentages may decline substantially after 6 months. Under storage conditions ($4^0$C and 70-80% relative humidity) seeds have been known to survive for up to 7 years with no loss of germination (Plazas, 2007). The persistence of natural seed banks has not been well documented, but they may endure for many years. Newly harvested seeds are dormant, requiring 3 to 6 months of storage before they will germinate (Jennings, 1963).

### 2.5.4 Propagation

Cassava is normally propagated by means of stem cuttings, which are known horticulturally as stakes. Stakes are typically at least 20 cm long, and have 4 to 5 nodes with viable buds. Stakes must be transported carefully to avoid damage, and may be treated with agrochemicals to prevent pest or disease attack during establishment in the new plants (Prospero *et al;* 2009). Stakes must be matured to the point that they do not dry out too quickly when planted, but must not be over-mature (Leihner, 2002).

## 2.6 Importance of the crop

Cassava has become an important crop in Ghana and the world over. According to Amaner (2011), the world annual production of cassava is over 158 billion tons. Yan *et al;* (2001) also confirmed that

amount is used for various uses including human consumption (58%), animal feed (22%), and other uses (20%)

### 2.6.1 Human Uses as Food:

Cassava-based dishes are widely consumed wherever the plant is cultivated; some have regional, national, or ethnic importance (Frederick *et al.*, 2008). Cassava must be cooked properly to detoxify it before it is eaten. Cassava can be cooked in many ways. The soft-boiled root has a delicate flavor and can replace boiled potatoes in many uses: as an accompaniment for meat dishes or made into purees, dumplings, soups, stews, gravies, etc. This plant is used in cholent, in some households, as well. Deep fried (after boiling or steaming), which can replace fried potatoes, with a distinctive flavor (Pypers *et al;* 2011).

#### 2.6.1.1 Fufu, eba and tapioca

In Africa, fufu, or cassava bread, is made from cassava. Fufu is made from the starchy cassava-root flour (Rajendran *et al*; 2000). Tapioca essentially a flavorless, starchy ingredient produced from treated and dried cassava (manioc) root is used in cooking. Tapioca pearls are made from cassava root.

It is used in cereals; several tribes in South America have used it extensively. It is also used in making cassava cake; a popular pastry. Cassava can also be used in making “eba”, a popular food in Nigeria.

#### 2.6.1.2 Gari

Gari is a creamy-white, granular flour with a slightly sour, fermented flavour from fermented, gelatinized fresh cassava tubers.

#### 2.6.1.3 Flour

The cassava root flour is also used to make cassava bread by boiling flour until it becomes a thick, rubbery ball (Diziedzoave *et al;* 2008). The flour is also made into a paste and fermented before boiling after wrapping in banana or other forest leaves. This last form has a long shelf life and is a preferred food to take on long trips where refrigeration is not possible (Yusif, 2013).

### 2.6.2 Animal feed:

About 70% of world cassava root production is used for human consumption either directly after cooking or in processed forms; the remaining 30% is used for animal feed and other industrial products, such glucose and alcohol (El- Sharkawy, 2004). According to FAO (2013), cassava has the potential to transport from access to livestock feed for poor farmers. The study said processing of cassava (raw) into pellets, chips and feed meal could directly boost the Ghanaian livestock sector by reducing the production costs. Global cassava utilization as feed is estimated at 34 million tonnes (FAO, 2004). Even though cassava is an important staple food in a number of countries, a large share is used as feed. It was reported by Hjorth *et al*; (2008) that, high costs of feed has been a major constraint in expanding the livestock sector, maize-based feed can constitute 60-75 percent of the total cost of production.

Cassava hay is produced at a young growth stage at three to four months, harvested about 30–45 cm above ground, and sun-dried for one to two days until it has final dry matter of less than 85%. The cassava hay contains high protein (20–27% crude protein) and condensed tannins (1.5–4% CP). It is used as a good roughage source for dairy or beef cattle, buffalo, goats, and sheep by either direct feeding or as a protein source in the concentrate mixtures.

### 2.6.3 Medicinal uses:

Cassava is not commonly used in herbal medicine, but indigenous people do employ it for various healing purposes. The leaves can be used as a styptic, while the starch mixed with rum has been used for skin problems, especially for children. Cassava may be a useful source of starch for people who are suffering from coeliac disease (gluten intolerance) as it does not contain any gluten at all. In herbal remedies, the roots of the cassava are made into a poultice and applied directly to the skin as a treatment for sores (Wingertzahn *et al*; 1999). The leaf, root, and flour obtained from the plant can also be used in a wash that is applied to the skin. In developing countries, tapioca starch made from the cassava plant is used to help restore body fluids. Cassava root starch may be used in Vitamin C supplements (Saidou, 2004).

### 2.6.4 Other uses:

Cassava starch is used as an adhesive, in cosmetics and for making paper (Arku and Kelly, 2001). The tubers of cassava is extremely rich in starch- in fact, it is the richest source of starch than any food plant (it contains up to 10 times as much starch as corn and twice as much as potatoes (Duke, 2013).

**2.6.4.1** Biofuel

In many countries, significant research has begun to evaluate the use of cassava as an ethanol biofuel feedstock (Graham *et al.,* 2000).

**2.6.4.2** Ethno medicine

The bitter variety leaves are used to treat hypertension, headache, and pain (Anderson and Ingram, 1993b). As cassava is a gluten-free, natural starch, it's use in Western cuisine as a wheat alternative for sufferers of celiac disease is becoming common (Dziedzoave , 2008)

### 2. 6.4.3 Growth and Yield of cassava

Crop Production basically involves the sowing or planting of a unit of propagation and the progression from the young Plant, through the subsequent phases of growth and development to harvesting of the economic yield (Anderson *et al*; 1993a).

Plant growth can therefore be explained as the progressive development of an organism; an irreversible increase in volume due to the division and enlargement of cells (Cline, 2007). On the other hand development is the progression through the morphological changes which occurs as a result of growth. Ranges of plant growth and development are controlled by internal regulators such as Gibberellin that are modified according to environmental conditions. The long-term climatic conditions for a region determine the type of vegetation in that region, and regional environmental factors affect growth and development of the plants. The processes of growth, including the three major functions that are basic to plant growth and development include the firstly; the process of capturing light energy and converting it to sugar energy, in the presence of chlorophyll using carbon dioxide and water (Asiko, 2008). Secondly, the process of metabolizing (burning) sugars to yield energy for growth, reproduction, and other life processes. Lastly, the loss of water vapour through the stomata of leaves (Mimbi, 2012). Osei (2009) therefore concluded that, generally, plant growth and yield is affected by two sets of factors which are environmental and genetic.

With genetic factors - Yield potential is determined by genes of the plant. Arku (2001) therefore reported that a large part of the increase in yield of cassava over the years has been due to hybrids and improved varieties. Other characteristics such as quality, disease resistance, and drought are determined by the genetic make-up. Nasaar and Ortiz (2007) also reported that, plant growth and development are limited by the environment. If anyone an environmental factor is less than ideal it will become a limiting factor

in plant growth (Walton *et al*; 1999). Limiting factors are also responsible for the geography of plant distribution. For example, only plants adapted to limited amounts of water can survive in deserts. Most plant problems are caused by environmental stresses, either directly or indirectly (Anisimov, 2007). Therefore, it is important to understand the environmental aspects that affect plant growth (Ano, 2003). The four most ecologically important environmental factors affecting rangeland plant growth are temperature, water (precipitation), light and humidity (Manske, 2000). Any factor in the plants' environment that is less than optimum, whether it is deficient or in excess, will limit plant growth (Funseca *et al;* 1968).

### 2.6.5 External factors influencing crop growth and yield.

The external factors affecting the growth and yield of cassava include;

#### 2.6.5.1 Temperature

Generally, temperature affects cassava growth directly and indirectly in almost all the physiological processes of the plant such as germination, photosynthesis, respiration, absorption and osmosis (Gallo and Sayre, 2009) and that cassava plants are able to undergo all these processes effectively when temperature is condusive. Basically, the quantitative difference between photosynthates produced in cassava by photosynthesis and the photosynthates exhausted by respiration is the growth which is in general measured by the dry matter accumulation in the plant as affected by temperature (Arku , 2001).

During the day adequate sunshine and high temperature increase the rate of photosynthesis and respiration whereas low temperature during the night reduces the rate of the two processes. Consequently such environment of sunlight and temperature is conducive to the plant growth. But assimilation process in cassava takes place within a certain temperature range (Smith and Whiteham 1997). Cassava growth

occurs within the limit of maximum and minimum temperatures (Grant *et al*; 1985). Each cassava plant has it's own minimum, optimum and maximum temperature known as their cardinal temperature which varies with the plant species. An approximate measurement of the temperature available from solar radiation, is an important factor because most of the plant's biological activity and growth occur within only a narrow range of temperatures, between $0^0$C and $50^0$C (Barbour *et al.*, 1987). High temperatures limit biological reactions because the complex structures of proteins are disrupted or denatured (Rogers, 1965). Although respiration and photosynthesis can continue slowly at temperatures well below $0^0$C if the plants are physiologically "hardened", low temperatures limit biological reactions because water becomes unavailable when it is frozen and because available energy is inadequate and a soil temperature of about 30°C; below 10°C the plant stops growing. Alves (2002) reported that the growth and yield of cassava is highly influenced by temperature relations within some specific micro-environment deferring from one variety to another. Temperature relation in cassava also affects sprouting, leaf formation, leaf size

(Rood and Major 1984). At lower temperatures, the sprouting of stem cuttings is delayed and the rate of leaf production is decreased. Temperature differentially also affects the different phases of root bulking (Hillocks *et al*; 2003). Root yields are also influenced by soil temperatures, especially during temperature regimes unfavorable to root growth (Baiyeri *et al*; 2000). Low temperatures tend to diminish the dependence of root bulking and initiation while moderate temperatures favour root growth and root to shoot ratios thus diminishes at higher and longer day lengths (Posthusmus, 1977).

**2.6.5.2 Light interception**

Generally, cassava plant produces carbohydrate using $CO_2$ and water with the help of light and chlorophyll (Afidgan, 2001). This process is called photosynthesis. Only visible light of the radiant

energy spectrum having 400 to 700 nm wavelength is used by the plant for photosynthesis known as Photosynthetically Active Radiation (Rood and Major, 1984; Li *et al.,* 2000). The leaf holds some part of the light falling on it which is called intercepted radiation and the rest is either reflected or passed downward through the leaf (Sam, 2011). The solar radiation falling on the green part of the plant affects the plant growth positively that is the more the fractional intercepted radiation in the green plants, the more the growth of the plant (Martin, 2008). Thus, plant growth can be expressed by the following equation.

$W = Es$

*Where, W = Dry matter*

Es = Conversion efficiency or light use efficiency.

Very low/high intensity reduces the rate of photosynthesis and may even results in the closing of the stomata. This result in reduced vegetative growth of the plants. At very high intensity cassava leaves become thick and dwarf. The leaves increase the rate of respiration and thus disturbs the photosynthesis-respiration balance (Balagopalan, 2002). It then causes rapid loss of water resulting in the closure of stomata (Allan, 2000). In addition to photosynthesis, light also plays a role in chlorophyll formation. In the absence of light etiolin is produced in the plant (Elanma, 2005). As a result, plants become yellowish which is called etiolating (Teramura, 1983). Any increase or decrease in solar radiation with species owning to minimal differences in day length in the tropics, photoperiod may play a role in the productivity of cassava. Higher light intensities favour root bulking (Bodlaender, 2011).

Interception of light in cassava therefore varies according to size, angle, orientation and surface features of the photosynthetic organ and is also influenced by changes in the arrangement of photosynthetic tissue within those organs (Howeler and Cadavid 1983). Leaf size can even change within an individual plant, smaller leaves being produced near the top has a higher level irradiance and larger leaves towards the interior and base where light levels are lower (Howeler, 2002). Another way to change light interception by cassava is by changing leaf angle and/or orientation (Howeler, 1981). Vertical arrangements enhance interception of light at low sun angles during early morning or late afternoon, and reduce interception at solar noon when radiation levels are highest (Fermont, 2009).

Leaves that are displayed horizontally will intercept less light (Fondong and Thresh 2002). Many cassava leaves can change their leaf angles and orientation in response to a change in light (Brugnolo and Bjorkman 1992). Some do this to increase interception while others do it to avoid high light (FAO, 1988). Another way of regulating light capture is to change leaf-surface properties (Funesca *et al*; 1968). For instance, many plants in high light environments increase the reflectance of their leaves by coating them with hairs or wax or even salt crystals (Jones and Briffia 1992). For instance, *Cotyledon orbiculata*, a crassulacean acid metabolism (CAM) plant from southern Africa, produces a wax coating which reflects 60% of incident light. If *C. orbiculata* is grown in low light, wax production stops and leaf reflectance drops to 9% (Robinson *et al*; 1988).

Photosynthetic tissue can be concentrated equally on both sides of a leaf (isobilateral) to maximize use of light absorbed from either side, or preferentially on one side (dorsiventral) as is common in species where leaves are predominantly horizontal (Fujihara, 2000). Chloroplast density and location within leaves is also sensitive to light climate, and energy capture varies accordingly (Gallo and Sayre 2009).

Alignment along vertical cell walls will reduce overall absorption of incident light. Brugnoli and Björkman (1992) reported that; cassava leaves absorbance can be reduced by % when chloroplasts move from the horizontal to the vertical walls of mesophyll cells (Grant *et al*; 1985). Under conditions where water is limiting, however, stomata conductance may be reduced, sacrificing photosynthesis in favour of slower transpiration (Robinson *et al;* 1988).

**2.6.5.3 Soil moisture**

Water is essential for cassava growth, development and other physiological processes of the plant. It is a principal element of protoplasm (Otu, 2008). Through the process of osmosis the hydrostatic turgor pressure of the cell increases which results in the plant growth (Hennessey, 2007).

With the rise of water potential in the plant, leaf expansion rate increase. Due to the lack of water, leaf is wilted and the growth is arrested (FAO, 2010). Again, at excessive soil moisture content abnormal growth occurs or even the plant may die (Cayan and Maurer 2008). Owing to continuous increase of water if the cell is saturated, differentiation is hampered (Aminu, 2000). Although cassava is tolerant to drought (Onwuene, 2012), higher yield levels are obtained with a larger moisture cycle or with conservation by mulching (IITA, 1990). Ghuman and Lal (1983) found significantly increase in yield and diameter with higher amount of moisture supply. Cassava (*Manihot esculenta crantz*) responds to decreases in water status by pronounced stomata closure and decreased leaf area growth. Many water deficit responses are thought to be regulated by abscisic acid (Alfredo and Setter 2000). When grown on very poor soils under prolonged drought for more than 6 months, the crop reduce both leaf canopy and transpirational water loss, but the attached leaves remain photosynthetically active, though at greatly reduced rates (Mim, 2003). The main physiological mechanism underlying such a remarkable tolerance

to drought was rapid stomatal closure under both atmospheric and edaphic water stress, protecting the leaf against dehydration while the plant depletes available soil water slowly during long dry periods (Fraser 2007a). This drought tolerance mechanism leads to high crop water use efficiency values (Chang, 1991). Although the cassava fine root system is sparse, compared to other crops, it can penetrate below 2 m soil, thus enabling the crop to exploit deep water if available (EL-Sharkawy, 2004).

#### 2.6.5.4 Relative humidity

Oxygen and carbon directly affects cassava growth by influencing the rate of transpiration (Asana, 2010). In addition, it also influences the physiological processes of the plant by controlling temperature. At very low humidity the pollen grain dries up (Aminu, 2000). Again, Issah, (2001) reported that, at very high humidity the pollen grains are attacked by fungi. As a consequence at both the conditions fertilization is impaired (Kang and Miller 1983). Cassava responds to changes in vapour pressure by closing its stomata and consequently reducing photosynthetic rate (CIAT, 2003). Earlier, Ford and Hicks (1992) reported that, varietal differences exist in response to vapour pressure deficit but whether or not they affect the ultimate yield is not yet known, because the environmental growing conditions have variable ambient relative humidity at different times of the day. Grange and Hand (1987) have reviewed all published work on the effects of, humidity on crops. They concluded that many of the effects of high humidity were due to localized calcium deficiency brought about by a reduction in transpiration (Fondong and Thresh 2002). Calcium is normally transported about the plant in association with the transpiration stream and is not usually redistributed by translocation in the phloem (Kawano, 2003). In general, any reduction in transpiration will induce calcium deficiency in organs that are rapidly expanding and needing a continual supply of calcium for such processes as the formation of new cell walls (Hennessey, 2007). There are instances, however, where increasing humidity can be beneficial

because it enables a positive root pressure to be developed (Filter, 1997). This can then deliver sufficient calcium to organs that have low transpiration rates (Fuglie, 2002). Grange and Hand (1987) also drew attention to the effects of high humidity on the incidence and development of fungal diseases, which can affect the yield and quality of protected crops, and the complex interactions of the effects of high humidity and of gaseous atmospheric pollutants (Plazas, 1991).



**2.6.5.5 Soil factors (physical and biological factors):**

Soil provides physical support to plant as well as supplies necessary water and nutrient elements for plant growth and development (Ijura, 2004). Cassava growth basically depends on these physical and biological properties of soil (Fraser, 2007). The main soil physical properties influencing cassava growth are soil texture and soil structural material (Chaudhry and Rasul 2004). Water and nutrient holding capacity of soil, soil aeration, drainage conditions and soil compactness are also influenced by soil texture (Nambia, 2013). In relation to cassava growth, soil biological factors are classified into otwo groups: beneficial and harmful. Arku (2001) reported that, fungi, bacteria, virus, nematode and so on affect plant growth and yield of cassava directly. Such microorganisms play important role in maintaining soil fertility (Asibey, 2010; Awuku, 2005). The harmful organisms are pests and disease causing organisms (Awuku, 2005; Asana, 2010).

**2.6.5.6 Effect of soil chemical properties on the growth and yield of cassava**

Cassava (*Manihot esculenta crantz*) is more productive than most other crops when grown on acidic and infertile soils but highly sensitive to over-fertilization (Ason, 2008). Awuku (2005) suggested that, the most important chemical factors influencing cassava growth are plant nutrient elements and soil pH. Crop growth is influenced by the supplying plant nutrient (Hillocks *et al;* 2000). Again, the nutrient

status of soil is greatly influenced by the mineral content of the soil, derived from the weathering of the rocks and minerals (Pujol *et al*; 2005). Nutrient availability increases with an increase in soil pH, while micro-elements show an inverse relationship (Pypers *et al*; 2011). Some cassava varieties prefers high acidity (Bray and Kurtz, 1945). But most cassava plants grows well in slightly acidic to neutral soil (Issurah, 2010). However, some plants grow well in alkaline soil (Nambia, 2013) and the crop is very responsive to better soil fertility and may require high levels of fertilization to reach its yield potential (Afidgan, 2009). Devon (2001) suggested that, the most important nutrients affecting cassava growth and productivity include; Aluminium (Al), Phosphorus (P) Potassium (K), Calcium (Ca) and Magnesium (Mg).

**i) Aluminium**

Cassava is well adapted to poor or degraded soils because of its tolerance to low pH, high levels of exchangeable Aluminium (Fermont, 2010). In some varieties the lower leaves show interveinal yellowing and necrosis, but in most varieties there are few recognizable symptoms; plants are small and lack normal vigour (Cock *et al*; 1984). In nutrient solution culture with high concentrations of Al, cassava plants were found to be small with a short and stubby root system (Loladze, 2002). Both Al toxicity and soil acidity stress can be prevented by the application of lime, which will decrease the Al saturation and raise soil pH (Awuku, 2005). Spain *et. al*; (2009) reported from an experiment that, rates of 0.5-2.0 t/ ha of aluminum were generally required to obtain cassava yields, while 3 t/ha of hydrated lime are required for maximum yield (Lobel *et al*; 2008).

**ii) Phosphorus**

Phosphorus deficiency is the most limiting nutrition factor for cassava grown on acidic soil. Low concentration of phosphorus in the soil solution (Balogoplan, 2002a). Ameg (2000) reported that,

phosphorus deficient cassava plants are generally short and spindly with thin stems, small and narrow leaves and short petioles. During periods of drought the upper leaves tend to drop down from the petioles (Robinson *et al*; 1988). The leaves are generally dark green while one or two lower leaves may be dark yellow to orange in some varieties with purplish necrotic white spot (Aura, 2000).

**iii) Nitrogen**

When grown on light textured and low organic matter soils, cassava tends to respond mainly to nitrogen (N) application. Injira (2004) reported that, nitrogen deficiency is commonly observed when cassava is grown on light textured soils with low organic matter content or in very acidic soils with a low rate of N mineralization (Lui *et al* ; 2000).

**iii) Potassium**

Cassava extracts large amount of K in the root harvest and long term fertility. Studies conducted by Afidgan (2009) indicate that, sooner or later K deficiency will become the most limiting nutrient if it is grown continuously without adequate fertilization. However due to the relatively large removal of Potassium (K) in the root harvest, continuous cassava cultivation on the same land may lead to K exhaustion and K eventually becomes the most limiting nutrient(Liu *et al;* 2008). Under normal soil conditions, cassava roots readily become infested with mycorrhizal fungi, which help the plant absorb Potassium (K) even at low external P concentration in soil solution (Dziedzoave, 2008). Potassium deficient plants are generally short, highly branched and with a prostrate growth habit (De Vires *et al*; 2010). In many varieties the upper internodes are very short and premature lignification of the upper stem. In some varieties, the upper leaves are small and chlorotic while in others few lower leaves are yellow with black spots and border necrosis (Cocky, 1989). Nweke et *al*; (1994) reported that the application of K 50-100kg/ha as potassium chloride would control the deficiency (Kenyon *et al*; 2006). Nutrient absorption and distribution are closely related to plant growth rate which depends on soil

fertility and climatic conditions as well as varietal characteristics (Lore and Associates 1990). Howeler, (1998) reported that, K application not only increased root yields but also their starch content (CIAT, 2003). In soils where P deficiency is not a serious problem, compound fertilizers with an $NP_20$-$K_20$ ratio of about 2: 1:3 or 2: 1:4 (Baiyeri, *et al;* 2008b) are recommended in order to supply enough K to prevent K exhaustion of the soil. Most K fertilizers are highly soluble and should be band-applied near the stake during the first two months after planting. In light-textured soils they should be applied in smaller quantities to prevent leaching (Buitelar, 2008).

**iv) Magnesium**

Magnesium deficiencies are often in acidic infertile soils (MOFA, 2001). It is characterized by interveinal chlorosis of the lower leaves which starts out as a slight yellowing of leaf margins and may eventually develop into necrosis of the leaf tips and margins (Devon, 2001). Symptoms appear first at the lower leaves and progressively move up (Nweke *et al*; 1994). It can be controlled by the application of 40-60kg mg/ha in the form magnesium oxide (Kleih *et al;* 1994).

**v) Calcium**

Calcium deficiency symptoms are pronounced in nutrient solution culture, but are seldom seen in the field (Ason, 2008). Significant responses of cassava to Ca application are also rare (Mim, 2003).

**vi) pH** pH affects the growth of plant roots and soil microbes (Tokimoto and Komatsu, 1978). Root growth favours a pH of 5.5 to 6.5 (Palmer, 1989a). Rainfall leaches ions through soil to form acidic conditions weathers rock and releases potassium, magnesium, calcium, and manganese (Li *et al;* 2000). The decomposition of organic material lowers soil pH (CIAT, 2003). Rainfall leaches ions through soil to form alkaline condition (Doku, 1967).

Cassava therefore grows well with a pH of 5.5-6.0. Higher soil pH above 6 indicates a soil type which is slightly acidic (Liu and Trumble 2007). When these occurs in cassava production, aluminium and manganese are bound in the soil structure which makes the root stop working as excessive plant nutrients is highly lost (Hagens, 2003).



**2.7 Effect of diseases and pest on the growth and yield of cassava**

Pests and diseases can affect cassava and have a serious impact on the economic output of a farm (Parmesan, 2006). These "pests and diseases" include insects, plant diseases, and invasive weeds (Cayan and Maurer 2008). Pests include also include mites, nematodes, weeds, bacteria, fungi, viruses, vertebrates etc. (Prospero *et al*; 2009) and are called biotic stressors.

These “biotic stressors” decrease agricultural yields, raise production costs, and limit the storability and marketability of the crop (Liu and Tremble 2007; Prospero *et al;* 2009). Pests and diseases hamper the productivity and sustainability of cassava, and some also affect the product quality (Mcdonald *et al*; 2009; Logan and Powell 2001). Some pests feed on non-marketable portion of the plant, causing yield losses (Chiezey and Egharevba 1987). Others also feed on the marketable portion of the plant, causing primarily quality loss whereas others also transmits organism that causes plant disease causing yield and quality losses (Ameg, 2000; Schneider *et al*; 2008). Among the biological factors that affect cassava production, diseases and pests still remain the major constraints that can bring African’s cassava production to a halt (Asan, 2004). The recent East African cassava Mosaic pandemic and the food shortages that resulted from it add value to the above statement (Amisimov, 2007). African cassava mosaic disease is still widespread and causes severe yield losses in the production systems that depend on susceptible cultivars (Adugna and Labuschagne 2002). Cassava bacterial blight, anthracnose, bud necrosis, leaf spots and root rot diseases affect the yield of cassava in

almost all producing countries in Africa (Allan, 2000). Information on yield losses due to diseases are often based on estimates but observations indicate that losses are significant in most of the cassava growing areas of Ghana (Emmanuel, 2013). In 2012, Mimanu reported that, the main diseases affecting the productivity of cassava involves basically;

Cassava mosaic disease caused by virus (Cock *et al*; 2007) and its common symptoms are the patches of normal green colour mixed with different proportions of yellow and white depending on the variety (Cline, 2007). These chlorotic patches indicate reduced amounts of chlorophyll in the leaves which affect photosynthesis and then cause reduction of yields (Amaanu, 2008). Improved varieties, use of healthy planting material, rouging and the use of resistant crop varieties can control those diseases (Secreto, 1951). Derrick (2007) investigated and found that cassava bacterial blight is also a disease affecting cassava which is caused by a bacterium (*Xanthomonas campestris* pv. *Manihoti*). Distinctive symptoms of the disease include the appearance of water soaked spots or lesions on leaves of infected plants (Yihong *et al*; 2008). The spots often start along the veins, margins and tips of leaf blades as it expand (Adams *et al;* 2009). The leaf dries or wilts and finally falls (Berrin *et al*; 2010). The disease can be controlled using resistant varieties, rouging, planting healthy plants, fallowing, crop rotation and quarantine (Sam, 2011). Anthracnose disease is also a commonly widespread in most of the cassava growing regions of Africa (Emmanuel, 2013), and it is caused by a fungus (*Collectothricum gloeosporioides*). It causes death of the stems and can be controlled by the use of resistant varieties, used healthy planting material as well as farm sanitation (Osuoe, 2010). Osmanu (2006) pointed out that, bud necrosis is another cassava disease is also caused by fungus and the symptoms are that; the necrotic areas are often covered with buds (Lobel, 2008; Logan and Powell 2001). The disease can therefore be controlled by using planting healthy materials and by good farm practices (El-Sharkawy and Cadavid 1997).

Lastly Naham (2004) reported of Brown and white leaf spot diseases as minor diseases caused by fungi. Aesidasha and Idana 2008 also demonstrated the key symptom as the appearance of few to several brown spots on the upper surface.



### 2.7.1 Growth partitioning of cassava.

During crop evolution increased yields have been derived largely from increased allocation of dry matter to harvested yields (Ben, 2011). Ecological environments are heterogeneous in both space and time (Uzun, 1996). They must modify their growth and development to suit the prevailing environmental conditions (Al-hassan, 1989). Most species can modify their crown shape and root architecture to favour the growth of their growing parts sited in resource-rich patches in heterogeneous environments (FAO, 1986). Therefore, if roots grown on low nitrogen are exposed to a localized region of high nitrogen, then the growth of roots is stimulated especially in that nitrogen-rich region

(Beeching *et al*; 2002). The controls that actually regulate the process of these morphological adjustments are still poorly understood (Byrne, 1984). It is widely assumed that, specific long-distance messengers operate to modulate growth partitioning in response to the environmental conditions (Trewavas, 1981).

# CHAPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 Location of study

The field experiment was conducted at the research fields of CSIR-Crops Research Institute of Ghana (CSIR-CRI) Fumesua in Ashanti Region from April 2013- April 2014. It falls within longitude 01°36°W and latitude 06° 43°.

### 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 1700mm and has a bimodal rainfall. The major rainfall season is from March to July while the minor rainfall season is from August 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.

### 3.3 Soil Description

The soil at the experimental site at Fumesua belongs to the Asuansi series and is classified as Ferric Acrisol with about 5cm thick top layer of dark grey gritty loam to gritty clay loam and a slope of 26%.

The sub-soil contains quartz gravel in a clay matrix. Mixed ironstone concretions and quartz gravel are contained in the clay matrix in some profiles. The soils are deep, porous, well drained, and well aerated with good tilth. It also has 16-20cm thick layer of sandy loam and slope of 1-5% percent. The soil at this location had been previously used for the cultivation of cassava and had been left to fallow.

### 3.4 Moisture retention

Moisture retention at Fumesua is fairly good in the sub-soil but the upper horizons tend to dry out rapidly during prolonged dry spells.

### 3.5 Experimental design and Treatments

The experimental design was a randomized completely block design with four (4) replications. There were 16 plots, each measuring 4x5m.The treatments consisted of four varieties of cassava. They include;

Ampong - $V_1$

Doku duade - $V_2$

Agbelifia - $V_3$

Debor - $V_4$

### 3.6 Description of the varieties

#### 3.6.1 Ampong

It is an improved variety developed and released by Crops Research Institute in Kumasi, Ghana in 2010. It is a high yielding variety and tolerant to diseases and pests especially African Cassava Mosaic Diseases (ACMD). It is open –shaped and branches much wider than Agbelifia and Doku duade.

### 3.6.2 Doku duade

It is an improved variety developed and released by Crops Research Institute in Kumasi, Ghana in 2005. It has a compact plant shape and branches at a higher height than Agbelifia. It is also tolerant to diseases and pests.



### 3.6.3 Agbelifia

It is an improved variety developed and released by Crops Research Institute in 2005. It has a cylindrical plant shape. Branching starts just at the base of the plant and progresses profusely. It therefore branches lower than all the varieties

### 3.6.4 Debor

It is a landrace used by the local farmers. It is susceptible to diseases and pests. It has an umbrella shape and branches at a very high height, and would be described as higher branching type.

## 3.7 Agronomic practices

### 3.7.1 Land preparation

The land was slashed, burned to control weeds emergence and to ensure better crop establishment.

### 3.7.2 Lining and pegging

Four hundred pegs were used in the pegging where each cassava stick were to be planted.

### 3.7.3 Planting

Healthy cuttings of 15-20cm long were planted at a spacing of 1m x 1m. Total number of cuttings was 400. 100 cuttings per each replication. Cuttings were inserted to the soil at an angle of $45^0$ such that only about a third of the cutting remains visible above the ground.

### 3.7.4 Field management practices

#### 3.7.4.1 Re-filling

Re-filling was done for cuttings that failed to sprout. This was done during the first 3 months after planting where most of the plants has sprouted.

#### 3.7.4.2 Weed Control

Hoe-weeding was done 2 months after planting to prevent weeds from competing with the crop for nutrients, water, light and space. Consequently, it helps in early canopy and tuber formation. Subsequently, three other weedings was carried out during 6, 9, and 10 months after planting.

#### 3.7.4.3 Diseases and pests Incidence

Diseases including African cassava Mosaic Disease, cassava bacterial blight, and Cassava Anthracnose disease were assessed during 3, 6, 9 months respectively after planting.

### 3.8 DATA COLLECTED

### 3.8.1 SOIL SAMPLING AND ANALYSIS

#### 3.8.1.1 Soil physical and chemical analysis

Soil samples were taken at depth (0-30cm) from the experimental site. These samples were taken to the laboratory to determine their physical and chemical properties. The samples were bulked, dried and sieved using a 2mm mesh sieve and the average value obtained.

### 3.8.1.2 Soil pH

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



### 3.8.1.3 Organic Carbon (% C)

The Walkley-Black wet combustion procedure was used to determine Organic carbon. Percent organic carbon was multiplied by 1.724 **(**The Van Bemmelen factor) to get percent organic matter.

### 3.8.1.4 Total Nitrogen (N)

The Macro Kjeldahl method described by was used. A 10g soil sample (< 2mm in size) was digested with a mixture of 100g potassium sulphate, 10g copper sulphate and 1g selenium with 30mls of concentrated suferic acid. This was followed by distillation with 10ml boric acid (4%) and 4 drops of indicator and 15mls of 40% NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14g of nitrogen is contained in one equivalent weight of $NH_3$, the percentage of nitrogen in the soil was calculated as follows:

$$\frac{14\ (A - B)X\ N\ X\ 100}{1000}$$

where,

A = Volume of standard acid used in the titration. B =

Normality of the standard acid used in blank titration

N=Normality of the standard acid.

### 3.8.1.5 Potassium

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

### 3.8.1.6 Available phosphorous

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



### 3.8.1.7 Exchangeable Bases (Ca, Mg, K, Na)

The exchangeable base cations were extracted using ammonium acetate ($NH_4OAc$) at pH of 7.0. Calcium and Magnesium were determined using the Ethylene Diamine Tetra acetic Acid (EDTA) titration method while potassium and sodium were determined by the flame photometer.

### 3.8.1.8 Growth and Development 3.8.1.9 Establishment data

Establishment data (sprouting) were taken 3 months after planting. Data were collected from a simple count within every plot. Measurements taken included the actual population (25 per plot) involving all the plants that survived.

### 3.8.2.1 Plant Height

Plant height was measured from three months after planting and then at every month up to the eleventh month. Measurement were taken from the soil level to the terminal end of each of the tagged plant using a graduated pole.

Plate 1: Measurement of plant height

**3.8.2.2 Number of branches**

Number of branches per plant was measured at three months after planting and then at every month from 6th up to eleventh month after planting.

**3.8.2.3 Canopy spread**

Canopy spread was measured at one month interval from 3-11 months after planting. Measurements were taken using a long pole at the two furthest ends of each tagged plant and the average value taken.

**3.8.2.4 Stem diameter**

Stem diameter was measured using vernier calipers at monthly interval during 3-11 months after planting. Measurements were taken from each of the tagged plants.

**3.8.2.5 Height and Length of branching**

The height and the length of the branching were also taken at monthly interval during 6-11months after planting using a long graduated pole from the soil level to the terminal end of the tagged plant.

### 3.9 Environmental response variables (Utilization of resources)

#### 3.9.1 Light interception

##### 3.9.1.1 Radiation Measurement

Intercepted photosynthetically active radiation (PAR) in each plot was measured with the Sun fleck ceptometer (model SF.80) from 5-9 months after planting (MAP). To measure PAR transmitted by the canopy, the Sun fleck ceptometer was placed horizontally above the tagged plant to record the incidence flux density. The ceptometer was then placed below the canopy perpendicular to the crop rows and the difference obtained (measurements above the leaf canopy and below the canopy) obtained. This is termed as photosynthetically active radiation (PAR). It is similar to the method described by Marshall and Willey (1983). All measurements were taken at solar noon on cloudless days.

##### 3.9.1.2 Soil moisture

Neutron probe (Dicot, Abingdon, UK)with aluminum access tubes (120 cm long with an internal diameter 50 mm) operating within 16 seconds count at an interval of 5cm was used. The probe was inserted into the soil at depths (0-25cm) and (25-50cm) within each of the replication to access the moisture uptake by the varieties. Readings were taken at one month interval from 6-9 MAP.

##### 3.9.1.3 Relative humidity, Leaf temperature and stomatal conductance

An automatic steady state diffusion porometer (Delta -T Devices) was used to measure humidity of the leaves in the stomatal chamber and the temperature of the leaves from 5-9 months after planting. Measurements were taken between 1200h and 1400h GMT at the mid-portion of a third fully-opened leaf parallel to the mid-rib of the plant.

### 3.9.1.4 Soil temperature

Soil temperature was measured using the soil thermometer. Recordings were made between 1200 h and 1400HGMT.



### 3.9.1.5 Canopy temperature

An infra thermometer was used to measure the temperature within the canopy. Measurements were also taken by selecting the open leaves that are photosynthetically active. Recordings were made between 1200h and 1400HGMT for every one month interval 5-9 months after planting.

Plate 2: Measurement of canopy temperature

### 3.9.1.6 Chlorophyll content

Chlorophyll meter was used to measure the chlorophyll content. Measurements were taken using the third fully opened leaf. Three recordings were taken from each of the tagged plant and the average reading recorded. Measurements were taken at the top most part; the middle and the bottom.

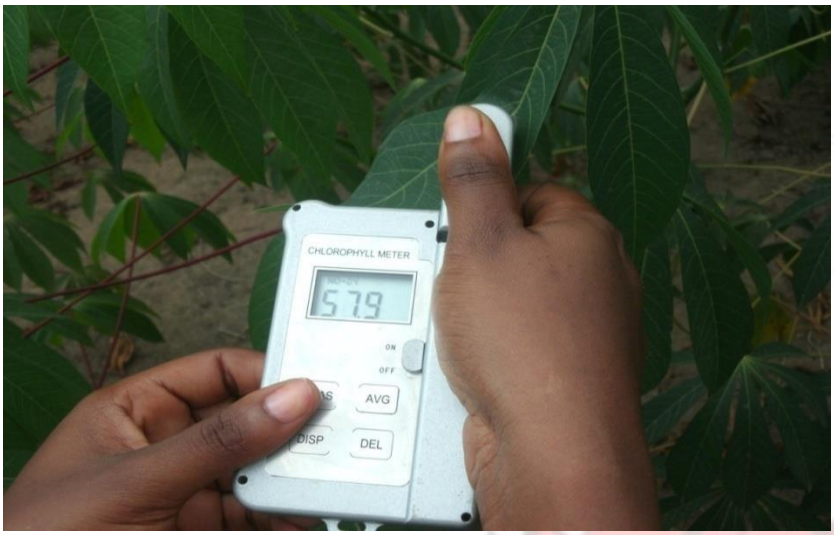


Plate 3: Measurement of leaf chlorophyll content

**3.9.1.7 Diseases and Pest**

Although the varieties have been genetically screened due to mutation diseases and pests were scored within 3 months interval. Diseases scored involved; African cassava Mosaic virus (ACMV) cassava bacterial blight (CBB) and Cassava Anthracnose disease (CAD). The scoring criterion used were ;

1=No symptoms observed

2=Mild chlorotic pattern on the entire leaflets or mild distortion at the base of the leaflets, rest of leaflets appearing green and healthy

3=Strong distorted pattern on entire leaf, narrowing and distortion of lower one-third of leaflets

4=Severe, distortion of two-third of leaflets

5=severe mosaic, distortion of four-fifths or more of anthers, twisted and misshapen leaves (source: Cassava in tropical Africa ref. manual pages 135.

**3.9.2 Other data collected.**

**3.9.2.1 Leaf folding/capping.**

Recordings were taken during 3 months interval within 3, 6, and 9months after planting.

### 3.9.2.2 Pest Attack

Attack by pest that bores hole in the soil attacking the tubers like rodent were also assessed for every 3 months interval during 3, 6, and 9.

Insect attack

Attack by insect pest like variegated grasshoppers which sucks nectar from the leaves were also assessed every 3 months interval during 3,6 and 9 months.

### 3.9.2.3 Correlation data

Correlation analysis between yield and environmental response variables was assessed using the Pearson Correlation Matrix.

### 3.9.3 Yield Measurements

#### 3.9.3.1 Number of Root/Plant

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

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

Plate 4: Counting of root number per plant at harvest

### 3.9.3.2 Root Mean weight

The mean weight was calculated as

$$\text{Tuber mean weight} = \frac{\text{weight of roots harvested}}{\text{Number of roots}}$$

### 3.9.3.3 Mean Fresh Shoot Weight

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

$$\text{Mean Fresh shoot weight} = \frac{\text{Total shoot weight}}{\text{Number of roots/stands}}$$

### 3.9.3.4 Harvest Index

Four of the tagged plants selected from each of the varieties at harvest was used to determine the harvest index. Weight of above ground biomass and that of the roots were recorded. The Harvest Index (HI) was calculated as;

Plate 5 : Weighing of total crop biomass

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

### 3.9.3.5 Root Dry Matter (%)

Sample of the selected roots were taken and chopped into smaller pieces. These pieces were mixed and 200 g taken and oven dried at 60$^{o}$c for 48 hours. The weight after constant value was recorded and dry matter content calculated as:

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

### 3.9.3.6 Root Yield (t / ha)

Four of the tagged plants were selected from the middle row from each of the replications and used for the root yield assessment.

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

Root yield (t/ha) = $\frac{\text{10,000 X Weight of roots from harvested stands}}{\text{Number of plants harvested}}$ (Hayford, 2009)


Plate 6: Root yield of Doku and Debor at harvest


Plate 7: Root yield of Agbelifia and Ampong

### 3.9.4 Starch Determination

Starch content was determined by the gravimetric method. Fresh roots were weighed into a bucket containing water attached to the gravimetric machine until stabled at the 5 kg mark. The cassava roots

were removed afterwards and placed in a hanging basket also attached to the gravimetric machine and readings were taken after being balanced at the 5kg mark of the weighing rod (Hayford, 2009).

### 3.9.5 Cooking quality (sensory evaluation).

Cassava roots were taken from each replications and the cooking quality i.e. mealiness test was done by a sensory evaluation panel, and assessed on a scale of 1 to 4 (1=very poundable, 2= poundable, 3= fairly poundable and 4=not poundable) after boiling the roots for approximately 40 minutes.

### 3.9.6 Data Analysis

Data were analyzed using the Genstat statistical package (12$^{th}$ Edition). Analysis of Variance (ANOVA) was used to determine the treatment effect on response variables. Differences between treatment means were determined using the Standard Error of Difference (SED) at 5% that is ($P<0.05$; $P=0.05$) level of probability.

# CHAPTER FOUR

## 4.0 RESULTS

Table 1 indicates the climatic conditions measured during the growing periods from July 2013- May 2014. The total amount of rainfall during the period was 936.4mm. The highest rainfall was recorded in September (255.4mm) and the lowest in August (7.4mm). The mean monthly temperature ranged from 26- 32º C

Table 1: Mean rainfall, temperature and relative humidity of Fumesua from July (2013) - April (2014)

| Months | Rainfall(mm) | Min. Temp.(ºC) | Max. Temp.(ºC) | Mean Rel. Humid (%) |
|---|---|---|---|---|
| | | 2013 | | |
| July | 153 | 20.6 | 31.2 | 26.2 | 91.2 |
| August | 7.4 | 21.7 | 30.5 | 25.8 | 89.1 |
| September | 255.4 | 20.4 | 32.9 | 27.2 | 90.1 |
| October | 171.4 | 19.9 | 33.6 | 28.2 | 89.1 |
| November | 104.8 | 20.8 | 34.1 | 29.2 | 87.6 |
| December | 5.8 | 21.0 | 34.8 | 29.2 | 74.7 |
| | | 2014 | | |
| January | 53.8 | 22.9 | 35.9 | 30.3 | 78.6 |
| February | 62.4 | 22.3 | 35.7 | 30.8 | 75.3 |

| | | | | | |
|---|---|---|---|---|---|
| March | 90.0 | 20.9 | 37.0 | 31.0 | 77.9 |
| April | 32.6 | 24.2 | 36.0 | 31.4 | 80.4 |



## 4.1 SOIL PHYSICAL AND CHEMICAL ANALYSIS

Table 2 indicates the soil physical and chemical properties at depth (0-30cm) of the experimental site. The texture of the soil was loamy fine sand. Available phosphorus content was 4.56mg/kg and soil total nitrogen was 0.15 which was moderately high. Exchangeable potassium was 0.53cmol/kg and was classified as moderate. The average value obtained for available phosphorus (4.56mg/kg) indicates a lower percentage. Results obtained for Mg (0.56 cmol/kg) and Calcium (1.81cmol/kg) also indicates a lower percentage. The pH of the experimental site (6.24) indicates a soil type which is slightly acidic. Results obtained 0.88 indicates a lower % carbon.

Table 2: Soil sampling and analysis

| **Soil properties** | **Average value** |
|---|---|
| Organic Carbon (%) | 0.88 |
| Organic matter (%) | 1.52 |
| Total nitrogen (%) | 0.15 |
| Available P(mg/kg) | 4.56 |
| **Exchangeable Bases(cmol/kg)** | |
| Potassium(K)(cmol/kg) | 0.53 |
| Calcium(Ca) | 1.81 |
| Magnesium(Mg) | 0.56 |
| Ph($H_2O$) | 6.24 |

| | |
|---|---|
| Sand (%) | 86.34 |
| Silt (%) | 5.92 |
| Clay (%) | 7.74 |
| Textural Class : | Loamy fine Sand |

## 4.2 GROWTH AND DEVELOPMENT

### 4.1.1 Plant height

Plant height showed significant differences (P< 0.05) among the varieties during 3 months after planting (Table 3). Treatments effects from 5 to 11 MAP showed that plant height of the Ampong and Agbelifia varieties were similar, but either effect was significantly (P< 0.05) higher than those of Doku and Debor varieties. At 4 MAP sampling, treatment effect of the Ampong varieties was significantly higher than those of Doku and Debor varieties. Treatment effect of the Agbelifia variety was also greater than that of the Debor variety only.

Table 3: Plant height (cm) of the varieties from 3-11 months after planting (MAP)

| | JULY. | AUG. | SEPT. | OCT. | NOV. | DEC. | JAN. | FEB. | MARCH |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2013 | | | | | 2014 | |
| VARIETIES | 3MAP | 4MAP | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |
| AMPONG | 153.5 | 153.6 | 181.9 | 183.5 | 206.5 | 284.4 | 288.0 | 289.6 | 315.4 |
| DOKU | 104.2 | 120.4 | 137.0 | 131.6 | 156.9 | 193.8 | 194.1 | 205.2 | 224.6 |
| AGBELIFIA | 138.6 | 138.7 | 179.2 | 179.6 | 181.9 | 274.2 | 278.1 | 286.6 | 311.9 |
| DEBOR | 102.7 | 106.2 | 132.9 | 134.9 | 167.8 | 134.9 | 238.4 | 239.8 | 249.6 |
| MEAN 255.3 | 124.7 | 129.7 | 157.8 | 157.4 | 142.6 | 246.8 | 249.7 | | 275.4 |
| SED | 11.0 | 10.1 | 7.1 | 20.5 | 14.7 | 15.2 | 14.5 | 12.3 | 19.7 |
| CV (%) | 12.5 | 12.5 | 6.[1] | 17.5 | 12.2 | 8.7 | 8.2 | 6.8 | 10.1 |

[1] **.1.2 Stem diameter**

effects on all sampling days were statistically similar.

Table 4: Stem diameter (cm) of the varieties from 3-11 months after planting

| | JULY. | AUG. | SEPT. | OCT. | NOV. | DEC. | JAN. | FEB. | MARCH |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2013 | | | | | 2014 | |
| VARIETIES | 3MAP | 4MAP | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |
| AMPONG | 14.9 | 15.3 | 18.4 | 22.0 | 22.9 | 22.9 | 24.2 | 24.9 | 27.8 |
| DOKU | 13.8 | 14.1 | 17.0 | 17.4 | 22.3 | 22.8 | 23.1 | 23.2 | 24.2 |
| AGBELIFIA | 18.2 | 18.9 | 19.2 | 21.1 | 22.0 | 23.2 | 28.0 | 28.2 | 29.4 |
| DEBOR | 14.5 | 14.7 | 16.3 | 18.7 | 19.9 | 21.9 | 22.1 | 23.8 | 26.7 |
| MEAN | 15.3 | 15.7 | 17.7 | 19.8 | 21.8 | 22.7 | 24.4 | 25.0 | 27.0 |
| SED | 1.8 | 2.0 | 1.0 | 1.4 | 1.6 | 1.3 | 1.1 | 1.3 | 1.4 |
| CV (%) | 17.2 | 18.7 | 7.8 | 10.7 | 10.6 | 8.7 | 9.1 | 9.8 | 10.0 |

### 4.1.3 Canopy spread

Canopy spread among varieties at 3MAP was not significant from each other. Meanwhile varieties shown significant differences during the 4 and 5 MAP. Varietal differences were also significantly different from each other in samplings from 6 to 11 MAP. During this period, canopy spread of Ampong and Agbelifia varieties were similar, and either varietal effect was significantly higher than those of Doku and Debor varieties. Treatments effects of the latter two varieties were not different on all sampling days.

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Varietal difference on all sampling days for the stem diameter was significant (Table 4). Stem diameter of the Doku variety on the 3, 4, 5, and 9 MAP was significantly lower than that of the Agbelifia variety only. At 6, 7 and 8 MAP samplings, treatment effect of the Debor variety was significantly lower than that of the Ampong variety only, except on 11 MAP. At 10 MAP, Stem diameter of the Ampong variety was significantly lower than that of the Agbelifia variety only. All other treatment

Table 5: Canopy spread(cm) of the varieties from 3-11 months after planting

| | JULY. | AUG. | SEPT. | OCT. | NOV. | DEC. | JAN. | FEB. | MARCH |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2013 | | | | | 2014 | |
| VARIETIES | 3MAP | 4MAP | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |
| AMPONG | 43.9 | 99.9 | 109.2 | 137.3 | 130.0 | 134.8 | 138.1 | 148.1 | 159.1 |
| DOKU | 43.3 | 98.1 | 105.2 | 107.7 | 92.50 | 97.2 | 97.2 | 107.0 | 122.5 |
| AGBELIFIA | 45.3 | 103.4 | 110.8 | 137.4 | 134.1 | 138.8 | 138.8 | 135.4 | 161.2 |
| DEBOR | 40.0 | 96.2 | 100.2 | 84.5 | 85.6 | 90.0 | 90.0 | 101.0 | 122.2 |
| | | | 106.4 | 116.7 | 110.6 | 115.2 | 118.7 | | |
| MEAN | 60.2 | 50.5 | | | | | | 123.1 | 141.3 |
| SED | 7.5 | 5.0 | 6.0 | 9.5 | 10.2 | 10.2 | 10.2 | 9.3 | 17.7 |
| CV (%) | 17.7 | 13.9 | 11.5 | 11.5 | 13.1 | 12.5 | 12.1 | 10.7 | 17.8 |

### 4.1.4 Number of branches

Number of branches showed no significant differences (P>0.05) among the varieties on 6, 7, 8, 9 and 10 sampling periods except on the 11MAP where effect of Ampong was significantly higher than those of the Doku variety. Values recorded ranged from 21-44, and the greatest values were at the 11 months after planting (Table 6).

Table 6: Branching number of the varieties from 3-11 months after planting

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. |
|---|---|---|---|---|---|---|
| | | 2013 | | | 2014 | |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |

| | | | | | | |
|---|---|---|---|---|---|---|
| AMPONG | 21.4 | 26.1 | 32.1 | 35.4 | 39.4 | 43.9 |
| DOKU | 22.1 | 26.3 | 31.1 | 35.3 | 39.3 | 41.5 |
| AGBELIFIA | 22.8 | 27.3 | 32.6 | 35.9 | 38.5 | 43.1 |
| DEBOR | 22.1 | 25.6 | 31.0 | 34.6 | 37.5 | 42.3 |
| MEAN | 22.1 | 26.3 | 31.7 | 27.5 | 38.7 | 42.7 |
| SED | 2.1 | 1.8 | 2.2 | 2.1 | 2.1 | 2.3 |
| CV (%) | 13.3 | 9.4 | 9.7 | 8.5 | 7.8 | 7.5 |

### 4.1.5 Length of branching

Varietal differences were significant on all days of sampling for length of branching (Table 7). The Doku varieties effect was lowest on all days of samplings and this was significantly lower ($P< 0.05$) than all other treatment effect. Length of branching did not differ significantly among Ampong and Agbelifia variety on all sampling days.

Table 7: Branch length (cm) of the varieties from 6-11 months after planting

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. |
|---|---|---|---|---|---|---|
| | | 2013 | | | 2014 | |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |
| AMPONG | 123.5 | 134.1 | 124.4 | 128.4 | 138.8 | 147.7 |
| DOKU | 67.4 | 70.1 | 76.3 | 81.2 | 89.7 | 98.6 |
| AGBELIFIA | 107.6 | 117.3 | 138.8 | 144.0 | 150.6 | 162.0 |
| DEBOR | 128.0 | 132.9 | 141.0 | 145.4 | 153.4 | 160.1 |
| MEAN | 106.6 | 113.6 | 120.1 | 124.8 | 133.1 | 142.1 |
| SED | 14.4 | 16.5 | 16.8 | 17.5 | 17.3 | 16.7 |
| CV (%) | 19.1 | 20.5 | 19.8 | 18.3 | 18.3 | 16.0 |

### 4.1.6 Height at branching

Height at branching showed a higher significant differences among the varieties (P<0.001). On all the sampling periods treatment effect of Debor variety was significantly higher than all other varietal effects. Ampong and Doku treatments effects were similar on all days and either effect was significantly higher than that of the Agbelifia variety (Table 8)

Table 8: Height at branching (cm) from 6-11 months after planting

| | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. |
|---|---|---|---|---|---|---|
| | | 2013 | | | 2014 | |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP | 10MAP | 11MAP |
| AMPONG | 23.8 | 23.0 | 21.3 | 23.5 | 27.6 | 26.3 |
| DOKU | 24.7 | 26.4 | 23.1 | 28.8 | 29.4 | 27.0 |
| AGBELIFIA | 10.2 | 10.9 | 12.1 | 12.6 | 11.7 | 15.3 |
| DEBOR | 42.8 | 31.3 | 35.8 | 39.8 | 39.8 | 42.9 |
| MEAN | 25.4 | 22.9 | 23.1 | 26.1 | 24.6 | 27.9 |
| SED | 1.6 | 1.3 | 2.3 | 1.3 | 2.9 | 3.0 |
| CV (%) | 8.8 | 8.1 | 14.2 | 7.2 | 16.7 | 15.0 |

## 4.2 Environmental response variables

### 4.2.1 Canopy temperature

Canopy temperature increased across all the sampling period (Table 9). Values obtained ranged from 20-90$^{o}$C. Canopy temperature differed significantly among varieties on all days of sampling. Treatments effects of Ampong and Agbelifia varieties were similar on all days except at 5MAP, and

on all days effects of these two varieties were greater than those of Doku and Debor varieties. Canopy temperature under the Debor variety, however, was significantly higher than that of the Doku variety at 9 MAP.



Table 9: Canopy temperature ($^0$C) of the varieties from 5-9 months after planting

| | SEPT. | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
|---|---|---|---|---|---|
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 27.4 | 38.1 | 39.8 | 40.4 | 85.5 |
| DOKU | 22.5 | 24.1 | 26.2 | 22.3 | 47.3 |
| AGBELIFIA | 36.2 | 35.0 | 35.3 | 46.7 | 89.1 |
| DEBOR | 20.0 | 26.4 | 22.2 | 21.5 | 55.6 |
| MEAN | 26.5 | 30.9 | 30.9 | 32.7 | 69.4 |
| SED | 1.4 | 2.6 | 2.7 | 2.2 | 2.4 |
| CV (%) | 7.5 | 12.1 | 12.2 | 9.7 | 4.8 |

### 4.2.2 Soil temperature

Soil temperature was also highly significant among the varieties ($P< 0.001$) (Table 10). Soil temperature under Agbelifia variety was the highest on all days of sampling, except 9 MAP. Also, on all days soil temperature under Debor variety was significantly lower than all other treatment effects.

Table 10: Soil temperature ($^0$C) of the varieties from 5-9 months after planting

| | SEPT. | OCT. | NOV. | DEC. | JAN. |
|---|---|---|---|---|---|
| | | | 2013 | | 2014 |
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 33.3 | 36.5 | 38.0 | 37.9 | 38.9 |
| DOKU | 27.9 | 33.3 | 33.1 | 32.8 | 33.9 |
| AGBELIFIA | 37.8 | 37.1 | 39.5 | 40.9 | 37.3 |
| DEBOR | 21.9 | 25.8 | 25.1 | 21.9 | 26.3 |
| MEAN | 26.5 | 33.2 | 33.9 | 33.3 | 34.1 |
| SED | 1.4 | 1.8 | 1.5 | 1.1 | 2.5 |
| CV (%) | 7.5 | 7.5 | 6.2 | 4.6 | 10.3 |

### 4.2.3 Leaf temperature

Temperature of the leaves was significantly different from each other ($P<0.001$) on all sampling periods (Table 11). Leaf temperature of the Agbelifia variety was the highest on all days except at 6 MAP. On all days, treatment effects of Ampong and Agbelifia variety were similar and either effect were significantly higher than those of Doku and Debor varieties. Soil temperature under the Doku varieties was also significantly higher than under the Debor variety on all days of sampling. Table 11: leaf temperature ($^0$C) of the varieties from 5-9 months

| | SEPT. | OCT. | NOV. | DEC. | JAN. |
|---|---|---|---|---|---|
| | | | 2013 | | 2014 |
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 34.3 | 42.2 | 38.5 | 38.2 | 74.9 |
| DOKU | 31.7 | 26.8 | 29.2 | 31.7 | 40.7 |
| AGBELIFIA | 36.5 | 38.8 | 43.3 | 39.6 | 78.2 |
| DEBOR | 23.4 | 21.7 | 22.1 | 23.5 | 34.3 |
| MEAN | 31.4 | 32.4 | 33.3 | 33.2 | 57.0 |
| SED | 1.5 | 2.4 | 1.9 | 1.1 | 2.3 |
| CV (%) | 6.5 | 10.5 | 8.1 | 4.8 | 5.8 |

### 4.2.4 Fractional light interception

Fractional light interception showed highly significant differences from each other (P<0.001) (Table, 12). Values ranged from 100-300. The Agbelifia treatment effect was significantly higher than all other treatment effects, except at 9MAP when Ampong and Agbelifia recorded similar effects. Ampong treatment effects were also greater than that of Doku and Debor varieties.

Table 12: Fractional light interception ($W/m^2$) of the varieties from 5-9 months after planting

| | SEPT. | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
|---|---|---|---|---|---|
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 118.0 | 124.2 | 204.5 | 218.3 | 290.9 |
| DOKU | 100.0 | 105.0 | 160.8 | 219.2 | 215.8 |
| AGBELIFIA | 124.0 | 196.1 | 279.4 | 291.8 | 301.9 |
| DEBOR | 76.5 | 102.7 | 113.4 | 181.4 | 202.9 |
| MEAN | 104.56 | 131.99 | 189.5 | 227.7 | 252.9 |
| SED | 2.0 | 1.5 | 18.5 | 14.9 | 14.1 |
| CV (%) | 2.7 | 1.6 | 13.8 | 9.3 | 4.5 |

### 4.2.5 Stomatal Conductance

Results of stomatal conductance varied among varieties on all the sampling days (Table 13). Stomatal conductance was greatest in the Agbelifia variety and this was significantly higher than the effects of the Doku and Debor varieties on all days of samplings. Treatments effect of the Ampong variety was

also significantly higher than those of Doku and Debor varieties on all days except at 5 MAP. Stomatal conductance in the Debor variety was significantly lower than all other treatment effects, except at 5MAP samplings.

Table 13: Stomata conductance ($ms^{-1}$) of the varieties from 5-9 months after planting.

| | SEPT. | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
|---|---|---|---|---|---|
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 212.1 | 249.8 | 288.8 | 263.2 | 203.6 |
| DOKU | 192.7 | 109.9 | 126.5 | 118.6 | 92.1 |
| AGBELIFIA | 236.4 | 299.4 | 305.9 | 291.4 | 213.7 |
| DEBOR | 205.6 | 83.6 | 102.8 | 84.2 | 54.7 |
| MEAN | 211.7 | 185.6 | 206.0 | 189.3 | 141.0 |
| SED | 10.1 | 19.2 | 4.6 | 4.3 | 4.9 |
| CV (%) | 7.3 | 14.6 | 3.1 | 3.2 | 4.9 |

### 4.2.6 Soil moisture at depth 0-25 and 25-50cm

Results obtained indicated that; soil moisture content under the Agbelifia variety was significantly higher than for all the other varieties on all days at 0-25cm depth on all days (Table, 14). Also, on all sampling days' treatment effect of Ampong variety was higher than for the Debor variety. Soil moisture at depth 25-50cm was similar under both Ampong and Agbelifia varieties on all sampling days and either effect was significantly higher than those under Doku and Debor varieties on all sampling days.

Table 14: Soil moisture at depth 0-25 and 25-50cm under the cassava varieties.

| | | (0-25cm) | | |
|---|---|---|---|---|
| | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP |

| | | | | |
|---|---|---|---|---|
| AMPONG | 26.8 | 28.1 | 29.0 | 28.9 |
| DOKU | 21.6 | 22.9 | 22.7 | 24.3 |
| AGBELIFIA | 32.7 | 34.3 | 35.9 | 40.8 |
| DEBOR | 18.1 | 16.1 | 15.9 | 18.8 |
| MEAN | 24.8 | 25.3 | 25.9 | 28.0 |
| SED | 2.1 | 2.9 | 3.1 | 3.5 |
| CV (%) | 12.1 | 16.3 | 16.7 | 17.6 |

(25- 50cm)

| | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
|---|---|---|---|---|
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 31.9 | 32.9 | 33.5 | 30.6 |
| DOKU | 21.8 | 22.5 | 24.8 | 23.1 |
| AGELIFIA | 35.7 | 36.6 | 37.1 | 36.3 |
| DEBOR | 18.5 | 18.6 | 18.8 | 18.8 |
| MEAN | 27.02 | 27.64 | 28.45 | 27.20 |
| SED | 1.87 | 1.75 | 2.01 | 2.94 |
| CV (%) | 9.80 | 9.0 | 10.00 | 15.30 |

**4.2.7 Relative humidity**

Humidity in the leaves also showed higher significant differences among the varieties ($P<0.001$). (Table 15). On all sampling days, humidity under Agbelifia variety was significantly higher than all other varietal effect. Humidity under the Debor variety was also significantly lower than all varietal means on all days, except at 7MAP, where its effect was similar to that of the Doku variety.

Table 15: Relative humidity (%) of the varieties from 5-9 months after planting

| | SEPT. | OCT. | NOV. 2013 | DEC. | JAN. 2014 |
|---|---|---|---|---|---|
| VARIETIES | 5MAP | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 76.9 | 77.3 | 74.7 | 70.2 | 79.2 |
| DOKU | 64.3 | 55.6 | 42.7 | 36.5 | 52.7 |
| AGBELIFIA | 84.9 | 84.1 | 87.7 | 82.4 | 88.5 |
| DEBOR | 46.8 | 32.2 | 42.4 | 26.6 | 33.5 |

| | | | | | |
|---|---|---|---|---|---|
| MEAN | 68.2 | 62.3 | 61.9 | 53.9 | 63.5 |
| SED | 2.5 | 1.6 | 2.3 | 2.6 | 3.6 |
| CV(%) | 5.2 | 3.7 | 5.3 | 6.7 | 8.1 |



### 4.2.8 Chlorophyll content

Chlorophyll content showed significant differences among the varieties ($P<0.05$) during some of the sampling period at the top, middle and the bottom leaves (Table 16). Results from the top leaves indicated that varieties were significantly different from each other only during the 9 months after planting ($P<0.05$) where mean of Doku variety was greater than all varietal effects. Results from the middle and bottom leaves also showed that varietal differences were significant only at 9 months after planting. In the middle leaves, chlorophyll content was greatest in the Doku variety, and this was significantly higher than all the varietal means. In the bottom leaves, varietal means were similar between Doku and Ampong varieties, but either effect was significantly higher than those of Agbelifia and Debor varieties (Table 16).

Table 16: Chlorophyll content of the varieties at the top, middle and bottom

| | | | TOP | |
|---|---|---|---|---|
| | OCT. | NOV. | DEC. | JAN. |
| | | 2013 | | 2014 |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 23.9 | 57.8 | 35.6 | 19.1 |
| DOKU | 30.8 | 56.6 | 28.9 | 27.1 |
| AGBELIFIA | 33.2 | 43.9 | 34.4 | 19.9 |
| DEBOR | 23.8 | 43.6 | 28.3 | 20.0 |
| MEAN | 28.0 | 50.5 | 31.8 | 21.6 |
| SED | 4.1 | 10.6 | 7.8 | 2.7 |
| CV (%) | 20.6 | 11.3 | 18.7 | 17.5 |
| | | MIDDLE | | |
| | OCT | NOV. | DEC. | JAN. |

| | | 2013 | | 2014 |
|---|---|---|---|---|
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 40.5 | 58.5 | 41.9 | 31.7 |
| DOKU | 44.1 | 56.1 | 37.9 | 37.5 |
| AGBELIFIA | 43.8 | 47.7 | 41.3 | 26.7 |
| DEBOR | 36.3 | 49.1 | 34.4 | 27.8 |
| MEAN | 41.2 | 52.9 | 38.9 | 30.8 |
| SED | 3.2 | 10.6 | 8.1 | 1.9 |
| CV (%) | 10.9 | 28.3 | 29.6 | 8.6 |

BOTTOM

| | OCT. | NOV. | DEC. | JAN. |
|---|---|---|---|---|
| | | 2013 | | 2014 |
| VARIETIES | 6MAP | 7MAP | 8MAP | 9MAP |
| AMPONG | 48.1 | 59.1 | 41.3 | 31.7 |
| DOKU | 49.3 | 47.5 | 39.4 | 36.5 |
| AGBELIFIA | 48.2 | 46.4 | 44.1 | 24.9 |
| DEBOR | 42.8 | 42.2 | 30.1 | 26.7 |
| MEAN | 47.1 | 48.8 | 38.7 | 30.0 |
| SED | 4.4 | 10.6 | 9.4 | 2.3 |
| CV (%) | 13.1 | 19.9 | 25.1 | 10.9 |

**4.2.8.1 DISEASE RESPONSE OF THE VARIETIES FROM 3, 6, 9 MONTHS AFTER PLANTING.**

Although the varieties were assessed of diseases (Africa Cassava Mosaic Virus), Cassava Bacterial Blight and Cassava Anthracnose Diseases; varieties showed no response to these diseases.

**4.2.8.2 YIELD COMPONENTS OF THE VARIETIES AT HARVEST**

Results obtained showed that, there were significant differences between the number of roots, average number of roots, number of stands, total plant biomass and the root weight ($P>0.05$) (Table 17). Top weight of the varieties shown no significance ($P>0.05$). Root length and root diameter showed significant differences ($P< 0.05$) for the varieties. Root diameter of Agbelifia was significantly higher than all the other treatments effects, all of which had similar effects. Root length was significantly higher in Ampong

than in all other varieties. Treatment effect of the Doku variety was also greater than that of Agbelifia variety. Other treatments effects were similar.

Table 17**:** Yield components of the varieties at Harvest

| VARIETIES | Num. of roots | Average num. of root | Num. of stands | Root weigh(kg) | Root length(cm) | Root diam.(cm) | Top weigh(kg) | Total Biom(kg) |
|---|---|---|---|---|---|---|---|---|
| AMPONG | 92.0 | 9.8 | 9.8 | 22.8 | 51.3 | 5.7 | 16.8 | 39.6 |
| DOKU | 88.0 | 9.0 | 9.8 | 18.9 | 44.9 | 5.1 | 14.9 | 33.8 |
| AGBELIFIA | 97.5 | 9.5 | 10.0 | 23.6 | 38.4 | 6.4 | 16.2 | 39.7 |
| DEBOR | 75.0 | 7.5 | 9.5 | 13.6 | 41.1 | 5.3 | 16.0 | 29.6 |
| MEAN | 88.1 | 8.9 | 9.8 | 19.7 | 43.9 | 5.6 | 16.0 | 35.7 |
| SED | 12.1 | 1.2 | 0.3 | 5.2 | 2.3 | 0.3 | 3.49 | 6.0 |
| CV (%) | 12.8 | 18.7 | 4.8 | 37.4 | 7.40 | 7.9 | 20.7 | 22.9 |

Differences between varieties for fresh weight was not significant (P>0.05) among all varieties (Table 18). Root dry weight was greater in Debor variety, which was significantly higher than that of Agbelifia variety only. Root yield was also greatest in the Ampong variety, and this was significantly higher than that of Debor variety only. All other treatment differences were not significant. The Ampong variety produced the greatest root dry weight, which effect was greater than that of Debor variety only. Varietal differences for harvest index and starch content were not significant (P> 0.05). The Debor variety produced the greatest dry matter content, but this was significantly higher than that of Agbelifia only. All other treatment effects were similar.

TABLE 18: Yield components of the varieties at Harvest

| VARIETIES | Fresh weight (g) | Dry weight(g) | Root yield(t/ha) | Dry root yield(t/ha) | Harvest Index | Dry matter (%) |
|---|---|---|---|---|---|---|
| AMPONG | 112.6 | 41.2 | 31.0 | 11.51 | 0.58 | 36.60 |
| DOKU | 115.2 | 40.9 | 21.0 | 7.43 | 0.55 | 35.63 |
| AGBELIFIA | 108.5 | 34.5 | 25.0 | 8.04 | 0.59 | 39.57 |
| DEBOR | 112.9 | 44.6 | 14.0 | 5.22 | 0.39 | 31.57 |

| | | | | | | |
|---|---|---|---|---|---|---|
| MEAN | 112.3 | 40.3 | 22.8 | 8.05 | 0.53 | 35.8 |
| SED | 6.05 | 3.56 | 6.90 | 2.61 | 0.12 | 2.40 |
| CV (%) | 7.60 | 12.5 | 22.9 | 12.50 | 7.90 | 9.80 |



TABLE: 19 Q

ıality Fac ors of the arieties

| VARIETIES | Starch | Cooking quality |
|---|---|---|
| AMPONG | 21.72 | 3.00 |
| DOKU | 23.00 | 2.00 |
| AGBELIFIA | 18.75 | 3.00 |
| DEBOR | 23.0 | 1.00 |
| MEAN | 21.54 | 2.00 |
| SED | 1.63 | 0.29 |
| CV (%) | 10.70 | 20.4 |

Cooking quality; 1=Very poundable 2=Poundable 3=Fairly poundable 4=not poundable

Treatment effect of the starch content indicated that, Debor was significantly higher than those of the Agbelifia variety. Cooking quality rather differed significantly with Debor and Doku being very poundable and poundable respectively. Ampong and Agbelifia were fairly poundable (Table 19)

**4.2.8.3 CORRELATION BETWEEN YIELD AND OTHER ENVIRONMENTAL RESPONSE VARIABLES**

The correlation between yield and the environmental response variables showed negative correlations for most of the yield components (Table 20). The results obtained indicated a positive correlation between canopy temperature; root length (r = 0.13), starch (r=0.58), root diameter (r =0.40) and dry root yield (r = 0.42) but treatment effect were not significant different from each other (P>0.05). Soil temperature also had a positive correlation with root diameter (r =0.42) and dry root yield (r = 0.40) at (P>0.05).

Leaf temperature also gave a positive correlation with starch(r=0.52) tuber length (r = 0.27), root diameter (0.38) and dry root yield (0.54) which was significant. Chlorophyll content also correlated positively to dry root yield (r = 0.089). Finally, Light interception also had a positively correlation with dry root yield (r = 0.39) at (P>0.05).

TABLE 20: Correlation between yield and other environmental response variables

| | Root length(cm) | Root Diameter (cm) | Dry matter (%) | Starch (%) | Dry root yield(t/ha) |
|---|---|---|---|---|---|
| Can. temp | 0.13 | 0.40 | -0.44 | 0.58 | 0.42 |
| Soil temp | -0.08 | 0.42 | -0.48 | -0.64 | 0.40 |
| Leaf temp | 0.27 | 0.38 | -0.47 | 0.52 | 0.54 |
| Chlorophyll | - | - | -0.48 | - | 0.09 |
| Light inter | - | - | -0.53 | - | 0.39 |

#### 4.2.8.4 CORRELATION BETWEEN ENVIRONMENTAL RESPONSE VARIABLES

Stomata conductance showed negative correlation with other environmental variables (Table 21). Stomata conductance showed a positive correlation between radiation(r=0.97) and humidity(r=0.99). Treatments effect were significantly different from each other at (P=0.001).

TABLE 21: Correlation between environmental response variables

| | Moisture | Radiation | Humidity |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Stomata conductance | -0.0001 | 0.97 | 0.99 |



# CHAPTER FIVE

# 5.0 DISCUSSION

## 5.1 Growth components

Assessment of the growing conditions (i.e. rainfall, temperature, solar radiation) showed that generally the climatic condition was ideal to support growth and yield (Yihong *et al*., 2009). Therefore, the major factors responsible for yield differences were likely due to genotypic variations among the varieties and

their response to varying environmental conditions (Ekanayake, 1998). Results obtained indicated that increase in plant height was as a result of seedling depth, time of planting and emergence (Nweke *et al;* 1994). This was reflected in the relative proportion of solar radiation intercepted by Agbelifia and Ampong. Nafziger (1991) reported that, as the height of plants increases the rate at which light is intercepted also tends to increase because taller plants tends to intercept more of the incident solar radiation than shorter plants. A similar experiment was conducted by Pommel (2002) who observed that taller plants intercepted more radiation than shorter ones. Additional observations showed that Agbelifia and Ampong had the greatest canopy spread which Debor had the lowest. Studies by Maddonni *et al.*, (2001) showed that, plants can maximize canopy light interception by increasing canopy architecture. Also, interception efficiency of both direct and diffuse irradiation increases with orientation of the leaves (leaves within horizontal laminane of the plants). Filek *et al*., (2000) suggested that as leaves adapt to a higher light gradient inside the canopy not only the inclination angles but also the canopy architecture helps the plant to intercept more of the incident solar radiation. Generally, the amount of radiation interception by the leaves canopy were higher for all the varieties and this might have contributed to lower chlorophyll content (FAO 1999; Hjorth *et al*., 2008). Results obtained shown that the middle part of the leaves accumulated the greatest chlorophyll content. This was because the bottom part of the leaves was wilting due to aging and the upper/top part was highly useful in partitioning of the photosynthate (Daniel, 2014) thus more of the chlorophyll was concentrated at the middle (El-Sharkawy, 2003).

Increase in moisture content at depths (25-50cm) presumed that, at higher depths roots of cassava are able to exploit more water than at lower depths (Young *et al*., 1983). Oosterveld and Nicholaichuk (1983) had proposed that, the deep rooting system of cassava serves as a defense mechanism against moisture stress, enabling the root to exploit more water even at a deeper soil depth. These characteristic

features exhibited supports the term environmental physiology of crop as defined by Evans (1998) as the response of plants to several changes within its environs as they grow and that, for plants growing in a particular environment where temperature is high, one of the adaptive trait to conserve it's moisture level is by closing it's stomata as leaf conductance reduced drastically at 9

MAP. Asare (2013) reported that stomatal response serves as a "first line of defense" protecting plants leaf from tissue desiccation even before low leaf water potential has developed and remain fully open until a threshold of $CO_2$ and radiation is reached.

These findings also deviated from a similar experiment conducted by (Boyers, 1979) who reported a reduction in $CO_2$ resulting in a decrease in photosynthetic rates. Other forms of adaptations favouring the survival and reproduction of plants under conditions of higher temperature include; dormancy, waxy cuticle, presence of thorns, leaf folding and thick barks (Robert *et al.*, 1999).

Increasing stem diameter might have been as a result of increasing number of branches (Fehr *et al.*, 1990). Stem diameter varied significantly among the four varieties. The highest was obtained for Agbelifia and the lowest for Debor varieties. Adjei (2012) reported that if the stems of cassava are not removed from the field for re-planting, a large amount of nitrogen (N) could be returned to the soil since cassava stems have been found to contain about 1.0-1.3% N. Varieties with a greater stem diameter such as Agbelifia and Ampong, have the potential to recycle large quantities of N into the soil through decomposition increasing the soil microbial activities. The number of branches compensated for the utilization of resource (light) as suggested by (IITA,1990) that the level of lateral branches may be a major factor in the formation of available photosynthate ; excess photosynthate therefore may result in more lateral branches being formed as indicated for both Agbelifia and Ampong obtaining the highest branching number.

## 5.2 Yield components

The amount of dry matter produced ranged from 30% in Debor and 40% in Agbelifia respectively. This was lower as compared to that reported by Williams (1974) with values ranging from 60-80%. Dry matter production by cassava depends upon the crop growth rate and the duration of the growing periods which in turns depends upon the variety, climatic conditions and the soil fertility most especially the climate (Howeler, 1988). Higher climatic conditions including temperature moisture and humidity favoured the varieties during the vegetative stages but during the reproductive stages, overall yield was affected thus strong negative correlation between resource- use and yield components. This according to Mishra and Singual (1992) was due to extremely higher temperature and humidity restricting most of the biological activities as well as increasing the potentials of roots damage (rotten) especially for Agbelifia, Ampong and Doku duade as observed during the period of harvest. This explains why these cultivars declined in yield drastically. Generally, temperature (leaf, soil and canopy) continued to increase rapidly throughout the experiment far above the maximum and minimum temperatures of the cropping environment which could affect the rate of metabolic processes. Abrol *et al*., (1991) suggested that, as the temperature of plant cell raises the velocity of movement of the reacting molecules increases, leading to more frequent inter-molecular collisions and more rapid reaction rates affecting crop yield. Jones and Briffia (1992) showed that virtually all reactions occurring in cells are catalyzed by enzymes whose action depends upon the maintenance of precise temperatures. As temperature rises in cassava production above $40^0$C increased molecular agitation tends to damage the tertiary structures, leading to reduced enzyme activity and dry matter production (Georgiadi *et al.,*1991). The plant fraction that made the largest contribution to the total dry matter (%) was found to be the roots. Egli *et al.,* (1985) on the contrary reported that, decreased dry matter production is associated with increased root yield (Jones *et al.*, 2003). Root yield obtained in the present study were quite low, as others had reported greater values

(Faisal *et al.*, 2007, MOFA, 2010). This might have also due to varietal superiority especially in their ability to utilize resources more efficiently through appropriate partitioning of assimilates (Grange and Hand 1987). Lower root yield in cassava have been attributed to higher disease prevalence (Bray, 1997), poor soil fertility, especially phosphorus (Howeler, 1980). The percent dry matter removed from the field as harvest index or storage roots (30-50%) was higher as compared to those obtained by (Williams (1974) which might have resulted in higher levels of nitrogen (Howeler, 1990). The greater harvest index by Agbelifia was also due to efficient translocation of dry matter produced into sink or harvestable portion (Ball *et al.*, 2000). Thus, the concept of photosynthetic source and sink fundamental to harvest index (Lui and Herbert, 2000). Adjei (2012) has reported that; with dry matter yields of between 18 and 24.9 t/ha the percent dry matter removed from the field as harvest index ranged from 35.7-57.8%. In similar experiment conducted by Kumudini *et al.*, (2001), the percent dry matter obtained from the soil as harvest index was about 40% when dry matter production was about 33.5t/ha.

### 5.3 Root Quality (cooking and Starch)

Starch content is an important parameter in the determining the final usage of cassava, especially for food and industrial purposes (Zierke, 1994). Generally, starch content of the roots recorded was lower as compared to those recorded by (Hayford, 2009). This could also be linked to the differences in genetic make- up of the varieties and their response to varying environmental conditions (FAO, 2000). This results confirms what (Ekanayake, 1988) reported that starch content of cassava roots depends on factors such as variety, soil type and climate. Also results obtained exhibited a positive correlation between starch content and cooking quality (mealiness test). This means that, farmers over the years have been using starch content as an index for cultivating particular varieties (MOFA, 2009) that suit their food needs. Farmers have therefore over the years attached importance to starch (%) either by their own effort or through the selecting of higher starch varieties for cultivation (Adjei, 2006). Debor had the highest

for dry matter and the starch content. It was also the best in terms of cooking quality and poundability. Other workers including Safo-Kantanka, Asare (1993) and Hayford (2009) have reported positive correlations between dry matter and cooking quality.



# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

The results presented showed variations in the performance of the varieties to different environmental factors. Light interception, soil moisture and humidity values were greatest in Ampong and Agbelifia varieties. This resulted in greater root yield in these varieties than the others. The results of the studies show that Ampong and Agbelifia varieties can be subjects of further research work especially in their cooking quality and poundability.

For the high yield potential, but poor cooking qualities, it is recommended that research must be carried out to improve their cooking quality and poundability through irradiation or other suitable means.

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