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INFLUENCE OF INTERCROPPING ON GROWTH AND YIELD OF CASSAVA

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BY

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(Crop Physiology)

BY

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SEPTEMBER, 2015.

DECLARATION

I hereby declare that this project work is the result of my own research and that no part of it has been presented for another degree in this university or elsewhere.

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ABSTRACT

The research was carried out at the Crops Research Institute Fumesua, KumasiGhana. The Purpose of the study was to determine the response of cassava growth and yield to intercropping, the land productivity of cassava intercropping system and competitive ratio of the cropping pattern. There were seven treatments comprising cowpea, soybean, cassava and maize in association to cassava/cowpea, cassava/soybean and cassava/maize in four randomized complete block design planted in the proportion of 1:1 cassava in the cropping system. In the study, intercropping system gave higher Land Equivalent Ratio (LER) for fresh root yield of 1.28 for cassava/cowpea and 1.06 for cassava/maize. Furthermore, cassava was more productive interms of competitive ratio when it was in association to cowpea, soybean and maize. Cassava root yield ranged from 26 to 36.1 t/ha-^{1} and the greatest yield was obtained from the cassava/cowpea intercrop which was significantly ($P < 0.05$) higher than cassava/soybean and cassava/maize. However, maize plant height was relatively higher in intercrop cassava than sole maize. All other treatments effects were not significantly ($P > 0.05$) affected by the cropping system. Cropping pattern did not significantly affect cob length, number of grains per cob and grain yield. Shoot biomass of cassava was highest in the cassava/cowpea cropping system. When cassava was intercropped with cowpea, soybean and maize, initially the growth of the cassava was affected. When species were in direct competition for limited resources, an increase in yield of one component causes a proportionate decrease in other crop species. Under such situations LER would not likely be significantly greater than 1.0. In the study, such phenomenon would have led to the poor performance of cowpea, soybean and maize yields.

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DEDICATION

This research work is dedicated to my dear wife, parents and children Adeliade Esiape, Clara Esiape, Junior Esiape and to my siblings Solomey and Divine.

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CHAPTER ONE

INTRODUCTION

According to Olasantan and Lucas (1992), the architecture and height of crop canopy as well as days to utilization of soil and aerial environment of the plants, contribute to the competitiveness and performance of component crops in intercropping. Intercropping has been shown to be more efficient in resource utilization and improves the overall ecology of the system (Babatunde, 2000) as well as increases monetary returns to the farmers (Mbah *et al*., 2009). Intercropping based system in Ghana particularly in the humid zone, the transitional belt and coastal savanna is now gaining increasing attentions. The design of intercropping system depends on the specific local conditions and the prevalent climate situation. Cassava, one of the resilient and commonly grown crops in the country, has the potential to contribute greatly to the country‟s Agricultural Gross Domestic Product (AGDP) and improve the lives of the thousands of farmers engaged in cultivation of the crop. Cassava

(Manihot esculenta Crantz*)* plays an important role in the agro economics of most African countries, contributing significantly to basic food requirements in urban and rural areas. Cassava provides the livelihood of up to 500 million households countless processors and traders around the world. Cassava is grown throughout the tropics and could be regarded as the most important root crop in terms of area cultivated and total production (Ano, 2003). It is the basic staple of many people in the tropical and sub-tropical belt and raw material for numerous industrial applications, including food and feed. Cassava production is closely allied with, but not the cause of, poor farm households, a relationship perceived to exist because poor households are marginalized and often live in marginalized areas the same areas where cassava performs better than other crops.

It tolerates wide range of soil pH 4.0 to 8.0 and is most productive in full sun.

Development of market opportunities for cassava can therefore increase food security, especially for resource-constrained household and contribute substantially to poverty alleviation (Plucknett, 1998). Root and tuber crops are second in importance to cereals as a global source of dietary calories (Babaleye, 2005).

In Ghana, root crops consumption forms between 16 and 31% of per capita daily calorie consumption (GSS, 2005). Their ability to produce a high amount of starch per unit area compared to other root crops and its tolerance to marginal soils and flexibility in harvesting dates make it a popular crop amongst smallholder farmers. Plant spatial arrangements, planting rate and maturity dates must be considered when planning intercrops. Studies conducted by Li *et al*. (2003) and Mpairwe *et al.* (2002) showed that the main essence of intercropping is to maximize use of resources such as space, sun light and nutrients, as well as to improve crop quality and quantity.

The need to maximize land productivity is becoming more evident in the humid tropics because of high population pressure and other human activities competing with agriculture for the limited available land (Steiner, 1991). Multiple cropping systems are particularly prevalent in small farms in the tropics where they are means of increasing the efficiency or utilization of resources, which include land, water and solar radiation (Palaniappan, 1985). The efficiency is measured by the quantity of produce obtained per unit resource in a unit time. The need to create security against potential risk of monoculture has been one of the driving forces behind intercropping, especially among small holder farmers who depend to a large extent on the vagaries of nature and are, as such, exposed to a diverse level of risk in their production
(Muhammad *et al*., 2003; Tsubo *et al*., 2003).

Intercropping can be beneficial in increasing crop yield and land use efficiency (Amanullah *et al*., 2006). Cassava-based cropping systems are more prevalent because the crop is one of the most important food crops widely grown in several countries in sub-Saharan Africa. It is the most important root crop in Ghana and Nigeria in terms of food security, employment creation and income generation for farm families. It is well suited to intercropping with short-duration crops such as maize, cowpea, melon, okra and several leafy vegetables. The crops are selected on the basis of differences in growth habits and can be combined in either simple or complex mixtures.

Maize is the principal cereal associated with cassava in the humid tropics, probably due to efficient utilization of resources by the crops as a result of morphological differences in mixture components, though cassava growth could be initially retarded.
It is, however, possible to get a high relative yield of the sole crop (Amanullah *et al*., 2006). A number of improved/landrace cowpea types are cultivated in Ghana. In most cases spreading types are used in intercropping system whereas erect or semierect types are used for sole cropping (RTIMP-MOFA, 2009).

Cassava is often left to continue growing after the other short duration crops, such as maize have been harvested in the early season. Intercropping is a way of increasing the diversity of the farming ventures, it improves stability that result in risk spreading, pest and disease incidence.

In sub-Saharan Africa (SSA) cassava is mainly a subsistence crop grown for food by small-scale farmers who sell the surplus. It grows well in poor soils with limited labour requirements. Cassava is usually intercropped with maize and grain legumes.

The most significant problems of Ghanaian small scale farming systems are associated with crop mixtures grown in no distinct row pattern arrangement and that managing some field operations with the use of mechanical and chemicals weed control are becoming more difficult. Generally in an intercropping system, each crop should have adequate space to maximize cooperation and minimize competition between them. However, attention is paid to the specific local situations such as the climate, the choice of crop, the arrangement of crops space and time of maturity. Both inter-row and intra-row spacing will be determined by the type of variety or cultivar and growing pattern. More space between plant and rows will be required with spreading types relative to the upright growing pattern.

In most multiple cropping systems developed by smallholders, productivity in terms of harvestable products per unit area is higher than under sole cropping with the same level of management (Francis, 1986). Yield advantages can range from 20 to 60% and accrue due to reduction of pest incidence and more efficient use of nutrients, water and solar radiation. Biodiversity in agro ecosystems can be enhanced in time through crop rotations and sequences in space through cover crops, intercropping, and agroforestry (Altieri, 1999; Malézieux *et al*., 2009). While modern agriculture has brought vast increases in productivity to the world‟s farming systems, it is widely recognized that much of this may have come at the price of sustainability (Tilman *et al*., 2002; Lichtfouse *et al*., 2009).

Biological and socio-economic aspect of individual crop advantage of various cropping systems, can give response based on the observed detailed research demonstration. Farmers would like to choose the system that actually yields more as compared to the traditional agro- ecosystems.

Crop mixtures permit better functioning of complex mutualisms and beneficial interactions between organisms.

Cassava yields are generally low (20t/h) in Ghana, though yields could be as high as 48.7t/h (MoFA, SRID, 2010). The causes of low yields are varied. Recommended spacing of cassava is 1×1 m, sole cropping will therefore mean a lot of weed growth among many stands.

To prevent this farmers have adopted intercropping, where all sorts of crops are intercropped with cassava. This has led to rapid soil exhaustion and low productivity. Intercropping mixtures improve the diet of the farmers as well as increasing the biodiversity of the environment. While cassava is a major source of calories, a cassava-based diet is low in protein, iron, zinc and vitamin A. Over the years, research on best crop combination with cassava has not been undertaken. This is the time to conduct such research and make appropriate recommendation to farmers.

The main objective of the study was to evaluate the growth and yield of cassava under three intercropping systems. The specific objectives were:

i To determine the response of cassava growth and yield of cassava in intercropping
ii To determine land productivity and the most economic returns of cassava intercropping system iii To determine competitive ratio under cassava intercropping system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin, History and Distribution of Cassava

Cassava is a tropical root crop, originally from the Amazonia, which provides the staple food of an estimated 800 million people worldwide (FAO, 2013). Cassava is known to have originated from the North Eastern Brazil. The Portuguese distributed the crop from Brazil to countries like Singapore, Malaysia, Indonesia and India. The crop can best thrive in nutrients poor soils and hot climates. It soon became a staple food of native South American people and the Caribbean. Maize and cassava were introduced to the African continent where they have now become major staple crops. The cassava crop is the staple root crop for more than 500 million people across the tropics. It is the primary source of carbohydrates in sub-Saharan African and the 6^{th} among crops worldwide (Olsen and Schael, 1999). In the Far East, cassava was not known as food plant until 1835. In about 1850 it was transported directly from Brazil to Java, Singapore and Malaya. The production of cassava was increased and improved during the Second World War. It was until then when 98 percent of the cassava flour was produced in Java during the period 1919-41 (FAO, 1971).

Cassava crop is valued as a famine relief crop. It is known that in part of Far East during the Second World War many people survived or depends on the root. In Africa it is the principal source of food for many mining workers and industrial areas (FAO, 1971).

2.2 Origin and Distribution of Cowpea, Maize and Soybean

Cowpea (*Vigna unguiculata* (L) Walp) is one of the most ancient human food sources and has been used as a crop plant since time mmemorial (Production guide for cowpea, 2011). Lack of archaeological evidence has resulted in contradicting views supporting Africa, Asia and South America as origin. Literature indicates that cowpea was introduced from Africa to the Indian subcontinent approximately 2000 to 3500 years ago, at the same time as the introduction of other cereal crops like sorghum and millet, while others state that before 300 BC (Production guide for cowpea, 2011),

There have been speculations that the Northern part of the Republic of South Africa (former Transvaal region) was the Centre of origin of *Vigna unguiculata*, owing to the presence of most primitive wild varieties. Cowpea is believed to have originated from West Africa by some mining workers, because both wild and cultivated species abound in the region. It is also believed that it originated from Southern Africa. Its production has spread to East and Central Africa, India, Asia, South and Central America (Production guide for cowpea, 2011).

Maize (*Zea mays*) originated in the Andean region of Central America. It is one of the most important cereals both for human and animal consumption and is grown for grain and forage. Present world production is about 594 million tons grain from about 139 million ha (FAO, 2000). Maize is an important staple cereal produced in all agroecologies of West and Central Africa, with a demonstrated high yield potential in the savanna zones (FAO, 2000). In sub-saharan Africa, maize is mostly grown by smallscale farmers, generally for subsistence as part of mixed agricultural systems (FAO, 2000). Many researchers believe the introduction of maize to Africa is very recent compared to Europe and Latin America (Ristanovic, 2001).

Soybean is thought to have originated in Asia and was first introduced to Europe and North America as a forage crop (Caldwell, 1973). In some places it is still considered as a forage crop, if there is a need for extra forage, or if the soybean crop had been damaged too severely for use as a grain crop (University of Wisconsin-Extension, 1999; Johnston and Bowman, 2000). Koivisto (2003) found that some of the recently developed cultivars were able to produce up to 12 t ha^{-1} DM in southern England, although the average was 9.2 t/ha^{-1} DM across the varieties tested. The earliest known cultivation of soybean (*Glycine max* (L.) Merrill) in Africa was in Egypt in 1858, followed by Tunisia in 1873, Algeria in 1880. Other sources argue that soybean was introduced to Algeria by Trabut, a French agronomist at a government botanical station in 1896. Algeria, a French colony was important to France as a place for acclimatization of plants, especially soybean. The next record of soybean cultivation in Africa was in 1903 when they were grown in South Africa at Cedara in Natal and in the Transvaal (Production Guide of cowpea, 2011). According to Rhodesian Agricultural Journal (1906), soybean was first cultivated in Zimbabwe in 1906. The crop was later introduced to Mauritius in 1907.

2.3 Production levels of cassava and the various intercrops

FAO (2013) reported that cassava constitutes 22 percent of Ghana‟s agricultural GDP and one of Ghana‟s main staple crops with an annual production of above 10 million metric tonnes in the last decade. In terms of area harvested, cassava is now the second largest crop as it has been recently superseded by maize.

On the other hand, UNComtrade database allows for the identification of main trade partners of Ghana at least for years 2005-2008.

During this period Ghana exports of dried cassava were directed mainly to the US and the UK. An estimated 40% of Africans rely on the crop as a significant source of calories (Nweke, 2004).

FAO (2012) stated that nine percent of cassava production was traded internationally in 2010, mainly in Asia. Trade has increased considerably in recent years; 2012 trade estimates are 31.7% higher than 2011. Export is concentrated between South East Asia and East Asia (FAO, 2012). Two-thirds of global exports go to China, mainly for industrial purposes. Thailand exported 4.2 million MT of dried cassava and 1.7 million MT of cassava starch in 2010 and is the world‟s largest exporter. (http://evans.uw.edu/sites/default/files/public/EPAR_UW_Request_223_Cassava_Integrated_Value_Chain_Public_Version_03.05.13_af.pdf assessed on the June 30th 2014)

The production obtained in traditional cassava/maize intercrops was 600-800 kg/ha of maize and 10-15 t/ha of fresh cassava roots, with very little use of purchased chemical inputs (CIAT, 1980).

Maize

Maize is the most important staple crop in Ghana and accounts for more than 50 percent of total cereal production in the country. The bulk of maize produced goes into food consumption and it is arguably the most important crop for food security. The development and productivity of the livestock and poultry sectors could also depend on the maize value chain, since maize is a major component of poultry and livestock feed. Moreover, maize is the second most important commodity crop in the country after cocoa.

Rice is the second most important staple cereal after maize, with substantial and continuing growth in rice consumption over the last two decades (MoFA 2012; MiDA 2010).

Maize has been in the diet of Ghanaian for centuries. It started as a subsistence crop and has gradually become more important crop. Maize plays an important role in the economy of Ghana (Xedagbui, 2010). In Ghana, maize is produced predominantly by smallholder resource poor farmers under rain-fed conditions (SARI, 1996).Maize is the most important cereal crop produced in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO, 2008; Morris *et al.*, 1999). According to FAO (2010) the area planted to maize in West and Central Africa alone increased from 3.2 million in 1961 to 8.9 million in 2005. In the month of June, 2014 the United States Department of Agriculture (USDA) estimated that the World Corn Production 2014/2015 will be 981.12 million metric tons; around 2.04 million tons more than the previous month's projection. World Corn Production in 2013 was 981.89 million tons. In 2014, 981.12 estimated million tons could represent a decrease of 0.77 million tons or 0.08% in corn production around the globe (www.worldcornproduction.com assessed on 11th June, 2014**).**

Cowpea

Cowpea is one of the most important indigenous African legume crops, mostly in West and Central Africa. It is regarded as a key protein source for the urban and rural dwellers and plays very significant role as cash crop (Langyintuo *et al*, 2003). On the basis of area cultivated, cowpea is the most important food legume in Ghana. The bulk of production occurs in the savannah regions of Northern Ghana, although cowpea can be grown in all ecological zones of Ghana. The crop is considered the second most important legume in Ghana after groundnut.

An average of 143,000 MT is annually produced on about 15600 ha making the nation the fifth leading producer of cowpea in Africa. The crop annual growth rate for the area, yield and production for the period from 1985-1987 to 2005-2007 were 0.1%, 39.6% and 39.8% respectively (Bulletin of Tropical Legumes report, 2012). It has also been projected that the rate of growth for the period is between 2010 and 2020 would be 11.1 % for cowpea *(*MoFA, 2010). Farmers store and sell more than 60% of the produced cowpea when prices go up during the off-season

(CORAF/WECARD cowpea report, 2011). The report indicated that Gross Domestic Production (GDP) of the country is $409 per capita per year. Generally farmers receive total net income of 673.462 GHc /Ha or $481 of cultivated cowpea (Ghana report PRONAF, 2010).

In Ghana, households generate annual income of about GH¢760-800 through increased production due to two or three cycles production per year of improved cowpea varieties.

In Northern Ghana an additional income of between GH¢ 15 to GH¢ 16 million is generated yearly, at least 40% of this directly going to women farmers (MoFA, 2010).

Soybean

The United states Department of Agriculture(USAD) estimated in the month of May that, the World Soybean Production 2014/2015 will be 299.82 million metric tons around 15.78 million tons more than the previous months projection 283.79 million tons. This year"s 299.82 estimated million tons could represent an increase of 16.03 million tons or 5.65% in soybean production around the globe (www.worldsoybeanproduction.com assessed on 11th June, 2014**).**

2.4 Growth requirement for cassava

Cassava does best in tropical and sub-tropical regions of the world. The crop requires warm temperatures for optimal growth (25 and 32°C). The plants require at least 8 months of warm weather, thriving in regions with warm, moist climates with regular rainfall. Cassava can be grown in many types of soil, producing even in poor soil but will be optimally productive in well-drained, sandy clay loam with a pH between 5.5 and 6.5. Cassava is drought tolerant but does not tolerate water-logging.

Root production is maximized when temperatures are between 25 and 32°C. Cassava should be planted in full sun and is very sensitive to shading, which leads to low yields. (https://www.plantvillage.com/en/topics/cassavamanioc/infos/diseases_and_pest)

last visited on the 11/12/2014). Cassava is known to be a tropical crop, growing between 30°N and 30°S in areas where annual rainfall is greater than 500 mm and mean temperature is greater than 20 ^{0}. However, some cassava varieties grow at 2000 m altitude or in sub-tropical areas with annual mean temperatures as low as 16^{0}C. The important criterion is to determine the onset and duration of the rains and more importantly, the maturity period of the various crop varieties. (http://www.old.iita.org/cms/details/trn_mat/irg61/irg611.html). Cock (1985) stated annual average temperature must be around 20^{0}C with low fluctuations in temperature, 17^{0}C.

2.5 Climatic and soil requirement for various intercrops

Cowpea can be grown under rainfed conditions as well as by using irrigation or residual moisture. The crop thrives between minimum and maximum temperatures of 28 and 30^{0}C (night and day) during the growing season. The crop performs well in agro-ecological zones where the rainfall range is between 500 and 1200 mm/year. With the development of extra-early and early maturity cowpea varieties, the crop can thrive best in the Sahel regions where the rainfall is less than 500mm/annum. The crop is drought tolerant and well adopted to sandy and poor soils. However, optimum yield is obtained in well-drained sandy loam to clay loam soils with the pH between 6 and 7 (Dugje *et al*., 2009).

Maize (*Zea may*s L.) belongs to the family of grasses (Poaceae) and it is cultivated globally and considered to be one of the important cereal crops worldwide (IITA, 1991). The crop was domesticated in central Mexico (Matsuoka *et al*., 2002) between 9,000 and 6,000 years ago. FAO (2005) reported that the crop thrives best in well drained sandy loam soil with a pH of 5.7 to 7.5 and 500 to 800 mm of rainfall evenly distributed throughout the growing season. Maize is a warm weather crop and does not grow in areas where the mean daily temperature is less than 19^0C or where the mean in the summer months is less than 23^0C (Plessis, 2003).

The crop needs regular supply of water and suffers badly in times of drought. It requires a rainfall of about 600 to 1200 mm per annum which must be well distributed throughout the year (Awuku *et al.*, 1991). Water is critically needed two weeks before tasselling and two weeks after silking for effective production.

In West Africa minimum rainfall of 1,000 – 1300 mm per annum and well distributed is good for crop growth (Tweneboah, 2002).

2.6 Planting materials for cassava and mode of planting intercrop

Cassava is mainly propagated from stem cuttings. Under natural conditions as well as in plant breeding, propagation by seed is common. Howeler (1992) indicated that cassava can be planted as sole crop or intercropped with other crops. In Ghana, cassava is often intercropped with legumes and cereals. In the forest zone of the country, cassava can sometimes be intercrop with plantain and or cocoayam whiles in the Northern Ghana, intercropping are often seen with sorghum, groundnut, maize and millet. The best time of planting cassava does not only depend on the climatic conditions at the time of planting but also on marketing conditions at time of harvest (Howeler, 1992). Cassava is often planted in Indonesia widely-spaced rows with upland rice between rows and maize within the cassava row. In China, cassava is often interplanted among young maize plants. The study by (Howeler, 1992) conducted showed that, planting vertically or inclined produced significantly higher in the case when stakes were planted in the early dry season. Horizontal planting resulted in the highest sprouting percentage but that of inclined planting produced the highest yields. Howeler (1992) indicated further that intercropping with mungbean or soybean can be successful sometimes, but other times may result in complete crop losses due to drought or severe insect or disease problems. Peanut is a renowned intercrop as it can be grown on similar acid infertile soils as cassava. It does not suffer pest and disease problems and it protects the soil from rainfall splash, thus reducing erosion. Intercropping requires careful selection of the crops – and the most suitable varieties of each crop – to be planted, careful timing of planting, good fertilization and optimum plant densities and distribution (FAO, 2013).

Planting time has proved effective on the general performance of component of various intercrop. Mongi *et al.* (1976) indicated that planting cowpea simultaneously with maize yielded better. Early stage cowpea intercropped with corn provides intermediate results showing that cowpea reduces weed growth to some extend (Barbosa 2008).

2.7 Importance and value addition to cassava

Processing of cassava into value-added products can positively impact its commercial viability. Post-harvest processing removes naturally-occurring toxins, reduces the product‟s weight for transport, decreases losses resulting from root breakage and extends shelf life (FAO and IFAD, 2000). Estimated study in West Africa indicated that over half of all cassava is consumed in a fermented and roasted form called *gari*, which is a popular in both rural and urban households (Phillips *et al*., 2004). The extended shelf-life of *gari* has allowed significant domestic trade in this product in

Nigeria and Ghana, making cassava a „cash crop‟ for many West African farmers.

From FAO, value-added cassava products such as cassava flour, cassava starch and cassava chips have potential in the forms of wheat import substitutions, adhesive ingredients, and animal feed, respectively. Production of ethanol has increased tremendously in Asia. An estimated 780 million liters of cassava ethanol could be produced in China in 2012, requiring about 6 million MT of dried cassava (FAO, 2012). Cassava is generally traded in the form of dried chips and hard pellets. There is very little trade in fresh roots, given cassava‟s low value per unit of weight and short shelf life without post-harvest intervention.

Mechanization of post-harvest processing in Africa varies by country and is more common in Nigeria and Ghana (FAO and IFAD, 2000). According to FAOSTAT (2010), the entire continent of Africa exported only 12,048 MT of dried cassava and 1,081 MT of cassava starch. However, FAOSTAT‟s data for cassava exports does not include several countries, including Nigeria and Ghana. Sub-Saharan Africa lags behind global trends in the development of the cassava value chain.

The market value of cassava leaves in areas where they are consumed is often higher than that of the roots, indicating that their sale contributes significantly to farm household incomes (Olsen *et al*., 1999). The biggest gains in cassava production since 2000 have been in West Africa, where output rose by 60 percent, from 47 million to 76 million tonnes. Productivity has increased as countries in the sub-region recognized cassava‟s potential as an industrial crop that could help to diversify farmers‟ incomes, earn foreign exchange and generate jobs **(**Sanni *et al*., 2009).

2.8 Importance of the pulses used in intercropping

Cowpea play a vital role in providing soil nitrogen to cereal crops (such as maize, millet and sorghum) when grown in rotation, especially in areas where poor soil fertility is a major challenge (Dugje *et al*., 2009). Most often the plant does not require a high rate of nitrogen fertilization. The plant roots have nodules in which soil bacteria called

Rhizobia help to fix nitrogen from the air for crop utilization. Depending on variety, seed size, cropping system and viability of the seeds pulses such as soybean and cowpea requires about 12-25kg/ha (Dugje *et al.*, 2009).

Cowpea is considered a staple diet in Sub-Saharan Africa, especially in the dry regions of West Africa. Mapfumo (2011) made critical lessons and technical knowledge on the potential contributions of legumes to the farming systems. Reijntjes *et al*. (1992) reported that 30-60 kg N ha^{-1} $year^{-1}$ is added to the soil by legumes. Sanginga *et al.* (1996) reported that *Mucuna* accumulated in 12 weeks about 160 kg N ha^{-1} when intercropped with maize. Raji (2007) had also reported of higher production efficiency in maize-soybean intercropping systems. Intercropping with grain legumes fix atmospheric nitrogen and make some N available to the cassava crop. Although biological fixation cannot meet all the cassava nitrogen needs, it has some benefits. In Nigeria, after two years of cassava-soybean intercropping, incorporation of soybean residues led to yield increases of 10 to 23 percent (Makinde *et al*., 2007).

2.9 Effect of intercropping on cassava

Intercropping systems is known to influence yield variables of the component crops, such as harvest index, hundred seed weight, number of reproductive organs and number of seeds, within each reproductive unit (Carruthers *et al*., 2000). Intercrop system reduces weed growth (Tripathi and Singh, 1983; Weil and McFadden, 1991; Carruthers *et al*., 1998), thereby causing reductions in herbicide use. Intercropping also produces crops that can be harvested at different times during the year, increases total net income per unit area of land and reduces the risk of total crop failure (FAO, 2013).

Developmental changes in crop can be examined by investigating the manner in which yield components are being affected by alterations in cropping pattern.

For example, the harvest index (HI) indicates the amount of plant biomass that is allocated to grain, thus providing an indication of the ability with which the plant partitions resources between vegetative and reproductive structures (Fukai and Trenbath, 1993). Fukai and Trenbath (1993) also reported that intercrop systems may improve stability in yield, allowing more consistent yields. The efficient use of the resources also cause the reductions in inputs cost. Ofori and Stern (1987) stated that cereal–legume intercrops are among the most frequently used and most productive. Corn–soybean intercrops have shown to be more productive than corn monocrops (Ahmed and Rao, 1982; Putnam *et al*., 1985; Marchiol *et al*., 1992). The soybean component adds valuable nitrogen to the soil (Singh *et al*., 1986), and improves overall protein content of the resulting silage (Martin *et al*., 1990).

2.10 Ecology of intercropping system

Miguel and Nicholls (2004) have observed that an agro-ecological approach to improve tropical small farming systems must ensure that promoted systems and technologies are suited to the specific environmental and socio-economic conditions of small farmers, without increasing risk or dependence on external inputs. The ecological futility of promoting mechanized monocultures in tropical areas of overwhelming biotic intricacy, where pests flourish year-round and nutrient leaching is a major constraint and has been amply demonstrated (Browder, 1989). A more reasonable approach is to imitate natural cycles rather than struggle to impose horticultural simplicity in ecosystems that are inherently complex.

Ewell (1986) argues that successional ecosystems can be of particularly appropriate templates for the design of sustainable tropical agro-ecosystems. Building on this idea and the contributions of modern agro-ecology provide principles for agro ecosystem. A design emphasizing the development of cropping systems enhances nutrient capture and confers resistance to pests, thus reducing agro- ecosystem vulnerability while providing biological stability and productivity. Many agricultural scientists have argued that the starting point in the development of new pro-poor agricultural development approaches are the very systems that traditional farmers have developed and/or inherited throughout centuries. Such complex farming systems, adapted to the local conditions, have helped small farmers to sustainably manage harsh environments and to meet their subsistence needs, without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science (Denevan, 1995). To mimic specific ecosystem processes, one tries to duplicate all the complexity of nature. All that is needed is to select the right kind of diversity (adding one or two plant species), to achieve herbivore resistance, enhanced productivity and nutrient supply (Gliessman, 1998). Increasing species diversity enhances full utilization of resources such as nutrients, radiation and water thereby giving protection from pest and compensatory growth.

2.11 Economic Importance of Intercropping

2.11.1 Efficient resource utilization and yield advantage

Cropping systems aims at making efficient use of growth resources so that high productivity can be achieved (Papendick *et al*., 1976).

Multiple cropping is the most common traditional cropping system in tropical Africa. It provides the farmer with a variety of returns from the land and often increases the efficiency of resources utilization by combining variety of crops and reduces the risk of dependence on a single crop which may suffer from environmental or economic fluctuation. It also gives scope for increased labour use efficiency and provides early income (Prabhakar and Pulley1984). Mostly, farmers generally considered intercropping as a technique that reduces risks in crop production; if one member of an intercrop fails, the other survives and compensates in yield to some extent, allowing the farmer an acceptable harvest. Pest infestation levels are often lowered in intercrops, as the diversity of plants hampers movement of certain insect pests and in some cases encourages beneficial insect populations in the ecosystems. Stern (1993) has argued that N is not transformed directly between intercrops when one of them is a legume, although indirect transfer via the decomposition of residues in soil is possible but, direct transfer was not possible. Cassava is suited with short duration crops because of its initial slow growth as well as it length of stay in the field for 12 to 18 months.

Several studies by numerous scientists show that intercrop legumes may accrue N to the soil and this may not become available until after the growing season, improving soil fertility to benefit a subsequent crop (Ofori and Stern 1987; Ledgard and Giller, 1995). Yusuf *et al*., (2009) found that maize grain yield was 46 percent significantly higher when grown after soybean than after maize and natural fallow.

2.11.2 Insurance against crop failure

Farmers practicing crop association were found to be more productive than monoculture. Farmers involved in crop mixtures were able to obtain two or more crops on the same piece of land than it was previously with monocroopped. Having more than one crop allowed farmers to escape total crop failure interms of disaster. Crops in mixtures leads to pest and disease control due to the fact that, host life cycle is disturbed

(FAO, 13). Crop insurance is efficient risk management tool. Trenbath (1993) noted that pests and diseases were high in monocropping compared to
intercropping.

2.11.3 Soil conservation

Studies have shown that intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize alone (Ghanbari *et al*., 2010). Component crops obtained yield advantage because crops do not compete for similar ecological niches and that interspecific competition is weaker considering the intraspecific competition. Leihner *et al*. (1996) reported intercropping with forage legumes was greater than when intercropped with cassava sole cropping. Results indicated the forage legume was higher and biodiversity can lead to agro ecosystems capable of maintaining their own soil with various legumes. Intercropping with legumes is an excellent practice for controlling soil erosion and sustaining crop production (El-Swaify *et al*., 1988).

2.11.4 Improvement of soil fertility

Intercropping enhances the maintenance and the improvement of the soil. Pulses and cereal combination is considered one of the way of improving the status of the soil
fertility.

Pulses are protein rich source of food for most farmers in the rural dwellers. The residual effects of the pulses are highest in the next season crop when the remains are ploughed under the soil after harvest. Giller (2001) reported that soil depletion can still occur in grain pulses inter crop when the nutrients taken up or used by crop are not replaced with manure or fertilizers. It has been noted that deep rooting legumes crops such as pigeon pea, take up nutrients from the soil. These help recycle nutrients leached from the surface. Magdoff (1992) reported that farmers over relying heavily on petroleum based nutrients inputs creates, leaks of nutrients in expose bare soil between cropping season. He also stated that lower levels of organic matter accumulation reduced biological activity in monoculture. These suggest that the recycling of nutrients is always minimal in most agro-ecosystems where there is reduction in permanent biomass held within the ecosystems.

2.11.5 Control of pests and diseases

Pests and diseases can affect crops and have a serious impact on the economic output of a farm.Seran and Brintha (2010) noted that bud worm infestation in sole maize was greater than in maize intercropped with soybean. The number of corn borer in maize was reduced when it was intercropped with soybean. Sekamatte *et al.* (2003) reported that soybean and groundnut are more effective in suppressing termite attack than common beans.

The average percentage of maize stalk borer infestation was significantly greater in monocropped (70 percent) than in intercropped maize-soybean (Martin *et al*., 1990).

2.11.6 Erosion control

Intercropping systems control soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface runoff (Seran and Brintha, 2010). Kariaga (2004) found that in maize-cowpea intercropping system, cowpea act as best cover crop and reduced soil erosion than maize-bean system. Reddy and Reddi (2007) found that taller crops act as wind barrier for short crops, in intercrops of taller cereals with short legume crops.

The effectiveness of intercrops in reducing soil erosion depends on whether they have been able to produce enough foliage in time to protect the soil surface from rainfall. That may explain why intercropping serves as a means of soil erosion control (FAO, 2013).

2.12 Radiation use efficiency (RUE) in intercropping

Trenbath (1993) indicated that light interception is determined by crop geometry and foliage architecture. A higher and low canopy crop is to improve light interception and yields. In intercropping, a shorter crop needs to be planted between sufficiently wider row of the taller crops (Seran and Brintha 2010). The major factors that affect yield in relation to incident radiation in intercropping system are the amount of light intercepted and the efficiency with which intercepted light is converted to dry matter (Keating and Carberry 1993). Tsubo *et al.,* (2001) reported that the radiation intercepted was higher in maize-bean intercropping than the sole crop.

Tsubo and Walker (2003) found that intercropped bean with maize had 77 percent higher RUE than sole cropped beans. Keating and Carberry (1993) found that maize – soybean intercropping has better use of solar radiation over the monocrops. Other studies from SSA region had proven the same results (Reddy *et al.,* 1980; Ennin *et al.,* 2002).

2.13 Crop combinations in intercropping and types

Intercropping has been important in Ghana and other countries and continues to be an important practice in developing nations such as Nigeria. The diversity created by intercropping can be enhanced even further by integrating (single or mixed species). When two or more crops are growing together, each must have adequate space to maximize cooperation and minimize competition between the crops.

To accomplish this, four things need to be considered: 1) spatial arrangement, 2) density, 3) maturity dates of the crops being grown and (4) plant architecture. Intercropping is one way of introducing more biodiversity into agro ecosystems.

Increased crop diversity may increase the number of ecosystem services provided. Higher species richness may be associated with nutrient cycling characteristics that often can regulate soil fertility (Russell, 2002). The choice of crop combinations in intercropping systems is as a result of plant competition, but it could be minimized not only by spatial arrangement, but plant ability to exploit soil nutrient (Fisher, 1977). It is argued that legumes developed for specific geogragphic region may not strive or perform best in other region.

Intercropping of cereals and legumes best utilize different sources of N (Benites *et al.*, 1993; Jensen, 1996; Chu *et al.*, 2004). Studies have shown that cereal may be competitive than the legume for soil mineral N, but the legume can fix N symbiotically presumably, if effective strains of Rhizobium are present in the soil.

2.14 Land Equivalent Ratio (LER) or Land productivity

Land Equivalent Ratio (LER) defined as the total land area required under sole cropping to yields obtained in the intercropping (Mead and Willey, 1980).

Land Equivalent Ratio shows the efficiency of intercropping for using the environmental resources compared with monocropping with the value of unity to be the critical.

When the Land Equivalent Ratio is greater than one (unity) the intercropping favours the growth and yield of the species, whereas when the Land Equivalent Ratio is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures (Willey, 1979; Willey *et al*., 1980). Asynchrony in resource demand ensures that the late maturing crop can recover from possible damage caused by a quick-maturing crop component and the available resources, e.g. radiation capture over time, are used thoroughly until the end of the growing season (Keating and Carberry, 1993). By contrast, when the component crops have similar growth durations their peak requirements for growth resources normally occur about the same time. The land use efficiency measured by relative yields increased with increasing maize population. Planting cassava and maize in the same row, in interrow and in alternate row arrangements had no significant effect on maize grain nor on cassava root yields, the earliness of maize maturity notwithstanding.

Due to a compensatory relationship in the yields of cassava and maize interropping systems, the choice of an appropriate maize variety and maize population in cassava and maize intercrop system will depend on the relative importance to a farmer of the two crops (Ezumah *et al*., 1999). Muoneke *et al.* (2007) found that the productivity of the intercropping system indicated yield advantage of 2-63 percent as depicted by the LER of 1.02-1.63 showing efficient utilization of land resource by growing the crops together.

Raji (2007) had also reported of higher production efficiency in maize-soybean intercropping systems. Dahmardeh *et al*. (2009) reported a LER value of 2.26 for maize intercropped with cowpea. Such a large productivity gain with intercropping is only possible when the morphological characteristics of the two crops are highly complementary and different ecological niches are used, resulting in more efficient use of resources (Willey, 1979).

Soybeans improved the land equivalent ratios (LER) relative to corn monocrops (Martin *et al.*, 1990). In Italy, there was an 89% higher yield for the mixture relative to pure crops of soybeans, but only a 4% higher yield when compared to pure crops of maize (Marchiol *et al.*, 1992). Study conducted by Ezeibekwa (2009) showed that introducing groundnut and poultry manure into the cassavas/maize intercrop system, resulted in increased crop productivity evidenced by high LERs. Some reported gains in productivity involving legumes. The intercrops LERs were 13.8-40.6% cassava/flamingia (Richard, 2005).

2.15 Competitive ratio (CR).

The competitive ratio is an important tool to know the degree with which one crop competes with the other Iftikhar, (2006). Iftikhar 2006 further reported in the studies that sesame grown in association with mungbean, mashbean, soybean and cowpea utilized the resources more aggressively than the respective intercrops which appeared to be dominated.

In the experiment, regardless of the planting patterns, mungbean proved to be more competitive than mashbean, soybean and cowpea. In the past monocropping of grain legumes (pulses) was an usual practice among the growers but now-a-days the interest in growing food legumes in an intercropping system is increasing (Khan *et al*., 2001).

The competitive behaviour of components crops in different sesame-based intercropping systems in terms of aggressivity, relative crowding coefficient and competitive ratio have been reported by Sarkar and Chakraborty (2000), Sarkar and Sanyl (2000) and Sarkar *et al*. (2001). Land equivalent ratio is the most commonly used index for assessing competition in intercropping system in contrast to pure stands (Agegnehu *et al*., 2006).

Cover crop between the rows of maize and not in the same row results in a better distribution of the plants in space and probably reduced competition between the two crops. The interval from eight to ten days between the sowing dates also gave maize a sufficient growth advance over the cover crop, which allowed maize to be dominant over the cover crop throughout its growth cycle (Baldéa *et al.*, 2011).

2.16 Main aspect to be considered in cassava cereal-legume intercropping systems

Seran and Brintha (2010) indicated that intercropping system provides higher cash return to smallholder farmers than growing the monocrops.

Intercropping system has the ability to increase in the profitability and low fix cost of land in subsequent crop in the same field (Thobatsi, 2009). Higher yield advantage has been obtained in the intercropped than the sole crop. This has resulted in crop stability and more efficient nutrient utilization. Weed control and insurance to total crop failure has been realised. Viljoen and Allemann (1996) study shows that sole crop cereal requires a larger land area to produce the same yield as cereal in an intercropping system. Increased nutrient uptake in intercropping systems can occur spatially and temporally. Spatial nutrient uptake can be increased through the increasing root mass, while temporal advantages in nutrient uptake occur when crops in an intercropping system have peak nutrient demands at different times (Anders *et al.*, 1996). The beneficial effects of the intercropping to the cereal crops may accelerate soil nutrient depletion, particularly for phosphorous, due to more efficient use of soil nutrients and higher removal through the harvested crops (Mucheru-Muna *et al.*, 2010). Intercropping cereals with legumes have greater capacity to replenish soil mineral nitrogen through its ability to fix atmospheric nitrogen (Fujita *et al.*, 1992; Giller, 2001).

2.16.1 Crop maturity time

In intercropping the complementary effects and the biggest yield advantage of the crops occur when the component crops have different growing periods so as to make their major demands on resources at different times (Ofori and Stern, 1987). Enyi (1977) reported that crops with periods of maximum nutrient depends and moisture, aerial space, light could be suitably intercropped. Also Reddy and Reddi (2007) reported that, in maize green-gram intercropping system, the peak light demand for maize was around 60 days after planting while green-gram was ready to harvest.

2.16.2 Compactible crop.

In intercropping, choosing the right crop combination is very important due to the fact that plant competition could be minimized, not only by spatial arrangement, but also by combining those crops that best exploit soil nutrients (Fisher, 1977).

Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N (Benites *et al.*, 1993; Jensen, 1996; Chu *et al*., 2004), which is scarce in most soils of small-scale farms of SSA (Mugwe *at al.*, 2011; Palm *et al.*, 1997). The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil. However, some combinations have negative effects on the yield of the components under intercropping system. Odendo *et al*. (2011) reported that maize/bean intercrop is predominant in eastern Africa and whilst in southern Africa maize is intercropped with cowpea, groundnut and bamabara nut.

2.16.3 Time of planting

Several studies have proven the effects of the planting time on the performance of the components under intercrop. Barbosa *et al*. (2008) reported that intercropping corn with cowpea, especially when done early, provides intermediate results, indicating that cowpea controls weeds to a certain extent. Addo-Quaye *et al*. (2011) found that maize planted simultaneously with soybean or before soybean recorded significantly higher values of leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR), compared to when planted later.

2.17 Weed competition as constrains to production

Lawson *et al*. (2006) reported that weed reduces the yield of crops by competition for resource utilization and causes interference in the farm operations thereby increasing the cost of production. Weeding is a major labour requirement for cassava production and weed competition is a major constraint to yields (Fermont *et al*., 2010). Uncontrolled weed growth can result in almost total yield loss (Chew *et al*., 2012).
Herbicides can be a cost effective alternative to hand weeding in cassava (Chew *et al*., 2012). Larger farms and smallholder farmers in West Africa report more herbicide use than smallholder farmers in East Africa (Chew *et al*., 2012). Light, water and nutrients utilization may be more completely taken and converted to crop biomass by intercropping; this is the simultaneous growing of two or more crop species in the same field. This is as a result of differences in competitive ability for growth factors between intercrop components (Anil *et al*., 1998; Ofori and Stern, 1987; Willey, 1979). Vandermeer (1989) reported that in competition, the various components are not competing for same ecological niches and that intraspecific competition is stronger whiles interspecies is weaker for given factors.

Efficient utilization of available growth resources is fundamental in achieving sustainable systems of agricultural production. Grain legume and cereal intercropping may provide an ecological method; utilizing competition and natural regulation mechanisms reduce the need for fertilizer and to manage weeds with less use of herbicides (Nielsen *et al*., 2001).

Intercropping is seen as an ecological method that helps to manage pests, diseases and weeds via natural competitive principles hence allowing for more efficient resource utilization (Liebman and Dyck, 1993).

Intercrops may show weed control advantages over sole crops in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds (Olorunmaiye, 2010) or suppressing the growth of weeds through allelopathy effect.

2.18 Harvesting of cassava

Cassava is harvested approximately 12 months after planting, so harvesting can take place any time from March to October (in an average year). The largest percentage of the cassava root harvest comes onto the market in the early part of the wet season (May to July). Harvesting during the dry season (November to March) is not common, only small quantities are harvested (Ghana Case Study, DRAFT 2013).

FAO report stated that when the root is used as food, the best time to harvest is at about 8 to 10 months after planting: a longer growing period produces a higher starch yield.

However, harvesting of some varieties can be needed at any time between six months and two years (FAO, 2013). These attributes of cassava make it the world"s most reliable food security crop. According to Sam and Deppah (2009) harvesting labour accounts for 15-20% of cassava root production costs. Costs vary considerably based on location. Root of cassava are at times left in the ground after maturity and may be harvested as and when consumer request (Onyeka *et al*., 2005).Underground storage of root and delayed harvest become quite challenging where the incidence of root rot is high.

Roots can be processed into granulated flour, or into high quality cassava flour which can be used as a substitute for some of the wheat flour in bread and confectionary. Two recent cassava mutations have starch properties that are highly valued by industry (FAO, 2013).

IITA (2000) surveys of 16 states of the humid forest and moist savanna agroecologies in Nigeria indicated that root rots were recorded to be widespread constraints of cassava production. The allocation of dry matter to the storage roots varies from almost zero during the early stages to nearly 80 % of the daily dry matter production during the late growth stages. Basically relationship between total dry weights of the storage roots is linear, suggesting that the roots growth keeps with the rate of crop growth (Ekanayake *et al*., 1998).

Vanhuyse (2012) stated that sufficient roots are harvested from farms. Upon the roots harvested in Ghana approximately 50% of cassava is either consumed or sold as fresh roots to produce (at household level) boiled or pounded cassava (*Fufu*).

The remaining 50% approximately is turned to the following products:

- 25% used to produce *Gari* (roasted fermented cassava)
- 18% used to produce *Agbelima* (fermented cassava mash)
- 6% used to produce *Kokonte* (dried chips)
- 1% used for industrial purposes

Cassava is processed to control deterioration of roots and decrease toxicity. Due to its high perishability and potential high cyanide content fresh cassava roots should be processed within 1-2 days of harvesting. These factors, combined with high moisture content of approximately 70%, restrict the marketing and transportation options for cassava roots (Ghana Case Study, DRAFT 2013).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The experiment was conducted at the Council for Scientific and Industrial Research Crops Research Institute (CSIR-CRI) Fumesua between May 2014 and April 2015. Fumesua is on longitude 1° 32‟ W and latitude 6° 43‟ N. The topography at the site and its surrounding areas is undulating with gentle slopes. The average elevation is 295m a .s .l taken from GPS readings and corroborated from 1:25,000 topographic map of Ghana. The area experiences bimodal rainfall pattern with peak of rainfall experience in the month of June and early part of October. The major season is between (April-July) and minor season September- November. With the current climate change being experienced most of the amount of rains is in the early and midpart of October. The study area has total annual rainfall of 1345mm/year. The mean annual temperature ranges from 22-31^0 C. The soil type is of Acrisol Asuansi series (Adu and Asiamah, 1992).

3.2 Experimental Design and Treatments

The field layout was randomized complete block design with four 4 replications. The replications were divided into plots with two (2 m) alley or buffer zone. Plot size was 4 x 5 m (20 m^2) with total plot size of 566 m$^{2.}$. The field was marked into blocks of known areas with alley between each replication to enhance easy movement of materials and agronomic operations.

The following intercropping patterns and their sole crops were studied

Sole cassava

Sole cowpea

Sole soybean

Sole Maize

Cassava/cowpea

Cassava/soybean

Cassava/Maize

3.3 Land Preparation and Planting materials

The field was slashed, ploughed, harrowed and was marked into blocks of known areas with alley between each replication. All planting materials were obtained from the CSIR-CRI, Fumesua, Kumasi. The cassava veriety used was "Sika Bankye" The variety is an early maturing with the following attributes: high in starch and contain 26-33% starch depending on the environmental conditions, soil fertility and soil moisture**,** not easily poundable and branches early in growth. Among the various varieties released "Sika bankye" is considered to be suitable for intercropping system (personnel communication Dr. Joe Manu-Aduening). The crops used as intercrop with cassava were maize, soybean and cowpea. The maize variety used was "Obaatapa" and the Soybean variety was "Anidaso", and cowpea "Nhyiraa".

3.4 Sowing

Cassava was planted first at a spacing of 1×1 m. The cassava were intercropped two weeks after sprouting with cowpea, soybean and maize. The experiment started at the onset of the rains on 30th May 2014.

Stakes/cuttings with 4 buds measuring about 25-25 cm long were planted at one per stand. The cassava sticks were inserted at an angle of 45^0 and buried under the soil showing only a bud above the soil surface. The cowpea, soybean and maize intercropped were planted the same day. The sole crop and intercrop were planted at plot size of 20 m^2. Each sole crop had 8 rows and that of intercrop have 4 rows of crops in number in the area planted. The sole crop for the soybean were planted 50 × 10 cm, whilst cowpea was planted at 50 × 20 cm, and maize 50× 40 cm because the cassava was sown at 1 × 1 m, all intercrops were made of one row of cassava and one row of maize, cowpea and soybean in their respective plots. Seeds were sown at 3-5 cm deep, whilst cassava stakes were slanted into the soil. All were planted with cutlass.

3.5 Cultural Practices: The following cultural practices were carried out during the study period.

3.5.1 Weed control

Weeding was carried out at 3 consecutive periods 4, 8 and 12 weeks after planting by the use of hoe.

3.5.2 Pest control

Aphids and pod borer were controlled by the use of sunperiphyfos at the rate 0.5L ha^{-1} to control aphid (*Aphis craccivora*) and pod borer (*Maruca testulalis*) on cowpea and soybean. The field was sprayed three times. Grain legumes were protected from major pests on a „minimum-protection" basis.

3.5.3 Fertilizer application

Fertilizer was applied to maize throughout the study period to accord with farming practice. Two weeks after planting NPK fertilizer was applied only to the maize at the rate of 90-40-40 of $N-P_20_5-K_20$ kg/ha by side placement.

3.5.4 Irrigation

Supplementary water source was applied with water horse during the short dry spell at the tasselling stage of the maize and pod development stage of the legumes. The water was applied every two other days till the fall of the rains.

Plate 1 and 2

Figure: Cassava intercrops with soybean, cowpea and maize at CRI Fumesua,

Kumasi-Ghana

3.6 Data Collection

All vegetative data was collected from 5 randomly selected plants from each plot for the legumes, miaze and 4 plants for the cassava. These plants were tagged for easily identification.

3.6.1 Cassava data

The following data were taken:

3.6.1.1 Plant height

Plant height was measured at 60 DAP, 120 DAP and 180 DAP using graduated meter stick from the selected plant at the ground level to the tip of the plants. The average was calculated for each plot.

3.6.1.2 Number of leaves

Number of leaves were counted at the date above for each plot, and the mean value was calculated.

3.6.1.3 Height at first branching

This was done using graduated measuring stick from the ground to branching point of the stem. The means for each plot was calculated.

3.6.1.4. Stem diameter

The stem diameter of the selected plants was measured with venier calipers and mean calculated for each plot. Measurement was done at 120 DAP.

3.6.1.5 Canopy development/Spread

The canopy spread of the cassava was measured taking into consideration the direction of the spread of the canopy. Two poles one placed at each end of the leaves by spreading steel meter rule from other end of the leave and stretched to the stream side of the canopy spread and the readings taking for plants in each plot. The mean value were calculated and recorded. Canopy were taken at 120 and 180 DAP.

3.6.1.6 Number of roots

The numbers of roots per plant were counted and the average number calculated for each plot.

3.6.1.7 Total root yield

All roots for each plot were weighed and converted to ton/hectare-^{1} for each plot.

3.6.1.8 Dry matter content

Roots were sampled from each plot and washed thoughrouly. Mechanical grater was used to grate the roots into smaller chips and 100 grams each were measured and oven dried at a temperature of 72^{0} C for 48 hours**.** Two replications were made and the mean weight was computed.

3.6.1.9 Harvest Index

Four (4) tagged plant were selected from each plot and the shoot (leaves and sticks) and roots weighed. The roots were then removed and weighed alone. The harvest index was then computed as the ratio of the roots (kg) weight to the weight of shoot (kg) plus roots. The formula used in calculating harvest index is below. Thus Economic yield /Biological express in 100 percent.

$$HI = \underline{Root\ weight} \times 100$$

$$Biological\ (shoot + root\ weight).$$

3.6.2 Cowpea data

3.6.2.1 Plant height

Plant height was measured from the ground level to the stem tip for each of the tagged plants and average calculated for each plot. Measurements were made at 28 DAP and 55 DAP.

3.6.2.2 Number of leaves

Number of leaves of each tagged cowpea plant were counted at the dates above and mean calculated for each plot.

3.6.2.3 Days to 50 % flowering

Days to 50 % flowering is the number of days 50 % of the plants had flowered for each plot. This was recorded and the average computed.

3.6.2.4 Number of pods per plant

Number of filled pod and unfilled pods of five tagged plants were counted and the mean calculated for each plot.

3.6.2.5. Number of seeds per plant

The numbers of seeds from 100 shelled pods were counted and the means calculated to obtain the seeds per pod, for each plot.

3.6.2.6 One hundred seed weight

One hundred seeds were selected randomly and weighed for each plot.

3.6.2.7 Total grain yield

Pods of plants from two central rows were harvested from each plot. The pods were threshed and seeds were oven-dried at 80^0 C for 2 days. These were weighed and each weight was converted to kilogram per hectare.

3.6.3 Soybean data

3.6.3.1 Plant height

Plant height at 21 DAP, 42 DAP, and 65 DAP were measured on tagged plants with steel meter rule. Measurements were taken from the ground to the stem tips.

3.6.3.2 Number of leaves

Number of leaves were counted at the same date plant height were taken for each plot, and the mean value was calculated.

3.6.3.3 Days to 50 % flowering

Days to 50 % flowering was calculated as the days when 50 % of the plants for each plot had flowered.

3.6.3.4 Number of pods/ plant

Number of filled pods and unfilled pods of five tagged plants were counted and the mean calculated for each plot.

3.6.3.5 Number of seeds per pod

Seeds from 100 randomly sampled pods from each plot were counted and mean calculated for each.

3.6.3.6 One hundred seed weight

One hundred seeds from each plot were selected and weighed.

3.6.3.7 Total grain weight

Pods of plants from two central rows were harvested from each plot. The pods were threshed and seeds were oven-dried at 60^0 C for 3 days. These were weighed and each weight was converted to kilogram per hectare.

3.6.4 Maize data

3.6.4.1 Plant Height

Plant height were measured from the randomly tagged plants in each plot from the ground to the stem tip, and the mean calculated for each plot. Data was taken at 4, 8, and 12 weeks after planting (WAP).

3.6.4.2 Number of leaves

Number of leaves was counted on the same date plant height were taken for each plot and the mean value was calculated.

3.6.4.3. Height at tasseling and ear height

Plant height at tasseling was also measured from the base of the plant to the leaf tip. Ear height was also measured from the soil level to the upper ear insertion node.

3.6.4.4 Cob size

This was measured as cob diameter and cob length. The diameter of the cob was measured by placing the cob on the graduated calipers and the value recorded. The length of respective cobs was measured by placing the shank in horizontal position and the calipers open to the length of the cob. The reading at the end of the cob tip is recorded and the mean calculated for each treatment.

3.6.4.5 Number of kernels

The total no of rows per ear were counted and multiplied by the average number of kernels per row to get the total kernel number per cob.

3.6.4.6 One hundred seed weight

This was measured by selecting one hundred seeds randomly from each plot and weighed.

3.6.4.7 Total grain weight

Maize plants from two central rows were harvested from each plot. The cobs were shelled and seeds were oven-dried at 60^0C for 3 days. These were weighed and each weight was converted to kilogram per hectare.

3.6.4.8 Moisture content (%)

The moisture percent content of soybean, cowpea and maize used for the intercrop were measured by the use of Moisture Tester-Dickey-John ® Mini GAC.

3.6.5 Estimation of intercrop productivity and competitiveness

3.6.5.1 Land productivity (***Land use efficiency)*** was determined by calculating Land equivalent ratio (LER) using (Mead and Willey 1980). This was used as an index of intercrop productivity. Land equivalent ratio of the crops was calculated as ratio of intercrop yield to yield of pure stand. The overall LER is simply the sum of LER of cassava intercrop, soybean, cowpea and maize. The competitive value was determined by calculating the ratio of the individual LER‟s of the three crops. The values were calculated as LER= LER Cowpea +LER Soybean +LER Maize.

$$LER = L_a + L_b + L_c = \frac{Ya}{Sa} + \frac{Yb}{Sb} + \frac{Yc}{Sc}$$

L_a, L_b and L_C are the LERs for the individual crops. Ya, Yb, and Yc are the individual crops yields in intercropping, whilst Sa, Sb and Sc are their yields as sole crops. The partial LERs are then summed up to give the total LER. According to Mead and Willey (1980) land equivalent ratio measures the effectiveness of intercropping using or utilizing the environmental resources compared to what would have obtained under sole cropping. Productivity is the measure of output per unit of input.

3.6.5.2 Competitive Ratio CR measures the ratio of individual LERs of the component crops and the proportion in which they were sown in the mixture. This gives a more desirable competitive ability for the crops. The competitive ratio for cassava-cowpea, cassava-soybean and cassava-maize in mixture were calculated by the formula proposed by Willey *et al* (1980). In a three-crop association, the "competitive ratio" (CR) is calculated by dividing the individual LER of one crop by that of the other crop, and correcting the result according to the space assigned to each crop.

The CR for crop *X* in association with crop Y is then: $\left[\frac{Ax}{Px}\ \ \frac{Ay}{Py}\right]\ \frac{Sy}{Sx}$

Where *Ax* and *Ay* are the yields of crops X and Y in association, and Px and Py represent the respective sole yields. Sy is the relative space occupied by crop Y, and Sx is the relative space occupied by crop X. The CR of crop Y is, by definition, the reciprocal value of CRx. Cassava/cowpea intercrops demonstrates the usefulness of this concept for the interpretation of results and for the determination of advantages or disadvantages of different agronomic practices in crop associations. Cassava planted at a spacing of 1×1 m was intercropped with cowpea, cassava-soybean and cassava/maize association distributed in 1 row at 0.5 m at either side of cassava.

3.6.5.3 Area time equivalent ratio (ATER)

The time duration upon which the field was dedicated to production is not considered for the calculation of LER but ATER as proposed by Hiebsch and McCollum (1978) take into consideration or accounts the land occupancy period of the crops. The total land area requires under sole cropping to give the same yields obtained in the intercropping is called LER.

Yield is generally a function of duration of land utilization, Hiebsch (1978) suggested area time equivalent ratio (ATER) as a better index for assessing yield advantage in intercropping systems. In the present study, both the component crops were of different maturity periods, thus, the calculation of ATER = [(Ya/Sa) Ta + (Yb/Sb) Tb]/T. The land occupancy period for cassava was 365 days, cowpea 65days, Soybean 115 days and maize 120 days..

To accommodate the temporal domains of the intercrops, time period the crop is taken to occupy the land from planting to harvest period make room for the calculation of Area Time Equivalent Ratio.

Where

Ya = yield of „a‟ in intercropping

Sa = yield of „a‟ in sole cropping

Ta = duration of „a‟

Yb = yield of „b‟ in intercropping

Sb = yield of „b‟ in sole cropping

Tb = duration of „b‟

T = total duration of intercropping system.

3.6.6 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) procedure and means compared using the Least Significant Difference (LSD) at 0.05 level of probability when the F-ratio is significant.

CHAPTER FOUR

RESULTS

4.1 Effect of intercropping on maize plant height

Maize plant height shown in Table 4.1 did not show any significant differences (P > 0.05) during sampling at both 2 and 3 MAP. However intercropping had significant effect on maize plant height at 1 MAP with height of maize plants in the intercrop treatment being significantly higher than those in the sole maize treatment.

Table 4.1 Effect of cassava intercrop on plant height of maize at 3 sampling periods.

	Plant height (cm) at		
Treatment	**1 MAP**	**2 MAP**	**3 MAP**
Cassava/ maize intercrop	43.55	121.12	176.8
Sole maize	41.27	121.20	175.2
L S D (5%)	1.91	NS	NS
C V (%)	10.6	14.5	10.8

4.2 Effect of intercropping on the number of leaves of maize

The number of leaves for maize intercrop was significant (P < 0.05) at 1 and 3 MAP (Table 4.2), but not at 2 MAP. At 1 MAP, number of leaves of the maize plants in the intercrop was significantly higher (P < 0.05) than those from the sole crops. On the other hand, at 3 MAP, leaf production in the sole maize crop was significantly (P< 0.05) higher than that from the intercrop.

Table 4.2 Effect of Maize cassava intercrop on number of leaves of maize plant

	Number of leaves at		
Treatment	**1 MAP**	**2 MAP**	**3 MAP**
Cassava/ maize intercrop	10	12	11
Sole maize	9	12	12
L S D (5%)	0.40	NS	0.40
C V (%)	10.5	7.0	8.4

4.3 Plant height of cassava

The results of plant height of cassava in sole and intercrop are presented in Table 4.3. On all sampling dates, plant height of cassava was greatest in the cassava/maize intercrop, and this effect was significantly higher than all other treatment effects at both 60 and 120 DAP samplings. At 180 DAP, however, treatment effect of the cassava/maize intercrop was significantly higher than those of cassava /soybean intercrop and the sole crop only in (Table 4.3).

Table 4.3 Plant height of cassava in various intercrops and sole crop at 3 sampling periods.

	Plant height of cassava (cm) at		
Treatment	**60 DAP**	**120 DAP**	**180 DAP**
Cassava/cowpea intercrop	22.77	65.8	148.3
Cassava/maize intercrop	33.38	115.0	157.6
Cassava/soybean Intercrop	25.52	59.2	114.4
Sole cassava	25.75	75.8	122.2
L S D (5%)	7.22	21.3	30.5
C V (%)	31.7	20.8	26.5

4.4. Number of leaves and canopy spread of cassava plants

The results of number of leaves at 60 DAP was not significantly (P > 0.05) affected by the cropping systems (Table 4.4). However, at 120 DAP sole cassava treatment recorded the greatest number of leaves of 105 per plant, and this was significantly higher than the effects of cassava/cowpea and cassava soybean intercrops only. All other treatment effects were similar (Table 4.4).

Table 4.4 Effect of cropping system on number of leaves and canopy spread of cassava.

Treatment	**Number of leaves at**		**Canopy spread(cm) at**	
	60 DAP	**120 DAP**	**120 DAP**	**180 DAP**
Cassava/cowpea intercrop	18	76	124.4	173.9
Cassava/maize intercrop	19	82	129.7	197.6
Cassava/soybean Intercrop	18	59	105.3	141.1
Sole cassava	21	105	136.8	175.8
L S D (5%)	NS	27.2	NS	45.3

C V (%)	28.7	40.0	37.4	31.0

Cassava canopy spread for all treatments were similar (P > 0.05) at 120 DAP sampling (Table 4.4). At 180 DAP, the treatment effect of cassava/maize intercrop was the greatest, but this was significantly higher (P < 0.05) than that of cassava/soybean intercrop only. Other treatment differences were not significant.

4.5 Cowpea plant height and Number of leaves

Cropping pattern significantly affected cowpea plant height on both sampling occasions (Table 4.5). On both days, plant height in the intercrop arrangement was significantly higher than in the sole crop pattern.

Cowpea leaf production on both sampling occasions was significantly higher (P < 0.05) in the intercrops than in the sole crops (Table 4.5).

Table 4.5 Effect of cowpea cassava intercrop on plant height and number of leaves of cowpea plants

Treatment	**Plant Height (cm)**		**Number of Leaves**	
	28 DAP	**55 DAP**	**28 DAP**	**55 DAP**
Cassava/cowpea intercrop	17.57	58.75	12	24
Sole cowpea	15.15	41.45	10	19
L S D (5%)	1.50	7.67	1.1	3.2
C V (%)	21.7	30.1	23.6	26.4

4.6 Plant height of soybean

Cropping pattern did not significantly (P > 0.05) affect plant height of soybean at 21, 63 and 84 DAP samplings. At 42 DAP, however, plant height in the intercrop was significantly higher than in the sole crop treatment.

Table 4.6 Effect of soybean cassava intercrop on plant height, leaves count and growth of the plant

	Plant height (cm) at			
Treatment	**21 DAP**	**42 DAP**	**63 DAP**	**84 DAP**
Cassava/cowpea intercrop	16.27	37.32	51.8	53.62
Sole cowpea	15.58	34.9	50.15	52.50
L S D (5%)	NS	2.29	NS	NS
C V (%)	20.5	14.9	15.3	20.8

4.7 Number of leaves of soybean plants

The results of soybean leaves are shown on Table 4.7. There was no significant (P> 0.05) treatment differences at 21 and 84 DAP. At 42 and 63 DAP samplings, the number of leaves in the intercrop was significantly higher than that of the sole crop.

Table 4.7 Effect of soybean cassava intercrop on number of soybean plants at 4 sampling periods

	Number of leaves at			
Treatment	**21 DAP**	**42 DAP**	**63 DAP**	**84 DAP**
Cassava/cowpea intercrop	10	45	20	13
Sole cowpea	9	13	16	11
L S D (5%)	NS	1.1	2.6	NS
C V (%)	8.37	19.4	35.0	28.0

4.8 Maize yield and components of yield in cassava/maize intercrop

There were significant (P < 0.05) differences in grain yield, with the sole maize recording greater yield than the intercrop (Table 4.8). Cob diameter from the intercropped maize was also significantly higher than that of the sole crop. However, cob length and member of grains per cob were not influenced by cropping system. (Table 4.8).

Table 4.8 Effects of cassava cropping system on components of yield and grain yield of maize

Treatment (cm)	Cob diameter (cm)	Cob length	No of grains cob^{-1}	Grain yield (kg/ha)

Cassava/ maize	4.55	13.78	438.00	1461
Sole maize	4.38	14.05	415.00	1779
L S D (5%)	0.04	**NS**	**NS**	269.4
C V (%)	4.02	10.3	21.3	20.3

4.9 Maize yield parameters in cassava/maize intercrop

The number of maize stands per plot and ear harvested were significantly affected by the cropping pattern. However, sole crop effect was significantly higher than the intercrop. However, grain moisture content at harvest was not significantly affected by cropping system (Table 4 .9).

Table 4.9 Effects of cropping pattern on maize yield parameter

Treatment (cm)	**Ear harvested/ plot**	**Number of stands/ plot**	**Moisture content (%)**
Cassava/ maize	27	30	13.03
Sole maize	49	61	13.18
L S D (5%)	6.0	4.3	NS
C V (%)	37.3	22.8	4.8

4.10 Cowpea yield and 100 seed weight

Intercropping did not significantly affect cowpea mean seed weight (Table 4.10). Seed yield was, however, affected by cropping system, as the yield of sole crop was significantly higher than that of the intercrop treatment. A significant difference in mean seed yield was due to the fact that, 100 seeds were weighed. However, grain yield took accounts of the plot size study was conducted.

Table 4.10 Effects of cropping system on cowpea yield and yield components

Treatment (cm)	**100 seed weight(g)**	**Grain yield (kg/ha)**
Cassava/ cowpea	12.0	387.5

Sole cowpea	11.8	550.0
L S D (5%)	NS	55.5
C V (%)	9.3	27.9

4.11 Cowpea yield components and seed moisture

Number of pods per plant, number of seeds per pod and seed moisture content were not significantly ($P > 0.05$) affected by the cropping system (Table 4.11).

Table 4.11 Effects of cropping system on cowpea yield component and moisture

Treatment (cm)	No of pod/plant	No of seeds/pod	Moisture (%) of seed
Cassava/ cowpea	38.75	13	12.0
Sole cowpea	22.75	12	12.1
L S D (5%)	**NS**	**NS**	**NS**
C V (%)	23.22	24.1	12.7

4.12 Soybean yield and mean 100 seed weight

Both 100 mean seed weight and grain yield significantly affected by cropping system and for both parameters, the sole crop treatment effect was significantly higher than that of the intercrop (Table 4.12).

Table 4.12 Effects of cropping system on soybean yield and mean 100 seed weight

Treatment (cm)	100 seed weight(g)	Grain yield (kg/ha)
Cassava/ soybean	9.75	388
Sole soybean	10.38	750
L S D (5%)	0.37	90.9
C V (%)	8.7	37.6

4.13 Soybean yield and mean seed weight components and seed moisture

Cassava/soybean intercrop significantly (P < 0.05) influenced the number of pods per plant with the intercrop treatment effect being significantly higher than that of the sole crop treatment. Numbers of seeds per pod and seed moisture content were not affected by cropping system (Table 4.13).

Table 4.13 Effects of cropping system on soybean yield components and seed moisture content

Treatment (cm)	No of pod/plant	No of seeds/pod	Moisture content (%)
Cassava/soybean	40	20	12.48
Sole soybean	25	20	12.33
L S D (5%)	4.05	NS	NS
C V (%)	29.5	0.0	4.9

4.14 Number of roots, root diameter, root weight and total above ground shoot weight of cassava

There were no significant (P > 0.05) differences in the number of roots among the intercrops and sole with the treatment effect of the cassava/maize intercrop being significantly higher than all the treatments (Table 4.14). All other treatment differences for root diameter were not significantly different from each other as indicated (Table 4.14). Cassava root weight was greatest in the cassava/cowpea intercrop, and this was significantly higher than that of cassava/soybean intercrop only. All other treatment differences were not significant (Table 4.14). Total above ground biomass was greatest in the cassava/cowpea intercrop and this effect was significantly higher than all other treatment effects.

4.15 Root yield, harvest index and dry matter content

Cassava root ranged from 26 to 36.1 t/ha (Table 4.14). The greatest yield was obtained from cassava/cowpea intercrop, which was significantly higher than cassava soybean intercrop only. All other treatment differences were not significant.

Harvest index was not significantly ($P > 0.05$) affected by cropping system (Table 4.15). Root dry weight was greatest in the sole cassava treatment, but this was significantly higher ($P < 0.05$) than that of the cassava/soybean intercrop only. All other treatment differences were not significant.

Table 4.14 Effect of cropping system on yield components of cassava

Treatment	No of root/plant	Root diameter	Root weight/plot	Shoot biomass(kg/ha)
Cassava/cowpea intercrop	7	49.8	14.43	64062
Cassava/maize intercrop	8	51.3	11.88	44938
Cassava/soybean	6	51.3	10.38	44000
Sole cassava	6	46.8	11.20	43688
L S D (5%)	**NS**	**NS**	3.59	18814
C V (%)	27.8	2.2	35.3	45.1

Table 4.15 Cassava root yield, harvest index and dry weight

Treatment	Root yield (t/ha)	Harvest index	Dry matter content (%)
Cassava/cowpea intercrop	36.1	0.37	32.86
Cassava/maize intercrop	29.7	0.40	30.46
Cassava/soybean	26.0	0.37	29.31
Sole cassava	28.0	0.40	34.19
L S D (5%)	8.97	**NS**	3.96
C V (%)	35.3	17.7	14.7

Table 4.16 LERs of grain yield of cowpea, soybean and maize in association with cassava

	LERcowpea	LERsoybean	LERmaize
Cassava/cowpea	0.704		
Cassava/soybean		0.517	
Cassava/maize			0.821
Total LERs			2.042

Fresh root yield

LER Cassava/Cowpea	LER Cassava/Soybean	LER Cassava/Maize	Total
1.28	0.92	1.06	3.26

Competitive Ratio of cropping systems

CR cassava	1.71
CR cowpea	0.54
CR cassava	1.78
CR soybean	0.56
CR cassava	1.29
CR maize	0.77

4.16 Land equivalent ratio (LERs) of cropping system

Table 4.16 shows the system productivity based on grain and root yields. All the results shows that cowpea, soybean and maize grain yields were not much productive but cassava intercrop in association was highly productive for cassava/cowpea and cassava/maize in fresh root yield. Both had LER of 1.28 for cassava/cowpea and 1.06 for cassava/maize in association, with the least recorded by cassava/soybean (Table 4.16). The productivity of cassava/cowpea intercrop was (120%) over cassava/maize.

4.17 Competitive ratio

In a three-crop association, the "competitive ratio" (CR) is calculated by dividing the individual LER of one crop by that of the other crop, and correcting the result according to the space assigned to each crop.

The CR for crop *X* in association with crop Y is then: $\left[\frac{A_x}{P_x} \;\; \frac{A_y}{P_y}\right] \frac{S_y}{S_x}$

Where Ax and Ay are the yields of crops X and Y in association, and Px and Py represent the respective sole yields. Sy is the relative space occupied by crop Y, and Sx is the relative space occupied by crop *X*. The CR of crop *Y* is, by definition, the reciprocal value of *CRx.* Cassava/cowpea intercrops demonstrates the usefulness of this concept for the interpretation of results and for the determination of advantages or disadvantages of different agronomic practices in crop associations. Cassava planted at a spacing of 1×1 m was intercropped with cowpea, cassava-soybean and cassava- maize association distributed in 1 row at 0.5 m at either side of cassava.

Competitive ratio for yield data: $\left[\frac{A_x}{P_x} \;\; \frac{A_y}{P_y}\right] \frac{S_y}{S_x}$

CR cassava $\left\{\frac{36.1}{28} \div \frac{0.3875}{0.55}\right\} \frac{1}{1} = 1.706$

CR cowpea $\left\{\frac{0.3875}{0.55} \div \frac{36.1}{28}\right\} \frac{1}{1} = 0.54$

CR cassava $\left\{\frac{26}{28} \div \frac{0.388}{0.750}\right\} \frac{1}{1} = 1.78$

CR Soybean $\left\{\frac{0.388}{0.750} \div \frac{26}{28}\right\} \frac{1}{1} = 0.56$

CR cassava $\left\{\frac{29.9}{28} \div \frac{1.461}{1.78}\right\} \frac{1}{1} = 1.29$

CR Maize $\left\{\frac{1.461}{1.78} \div \frac{29.7}{28}\right\} \frac{1}{1} = 0.77$

The Competitive Ratio values show that with the agronomic management practice almost a complete balance was maintained between two species. Cassava was slightly more competitive than cowpea, soybean and maize respectively. The distribution of a space at 1:1 ratio as indicated in the studies show the area occupied by the species. One major challenge using the CR index is the contribution of the area distribution factor. (Sy/Sx) is the determination factor accounting for either large or small differences between CR of the species under study. The results shows that in all cases cassava plant in associations was more competitive than all the species (cowpea, soybean and maize) under given management practices. In the study above the elimination of CR does not affect CR distribution factor since the Sy/Sx value is unity.

4.18: Effect of various cropping systems on the area time equivalent ratio (ATER)

Maximum utilization of space and time was observed among the crops in both intercropped and sole cropping. The better Area Time Equivalent Ratio (ATER) was due to better combined intercropped yield and temporal difference which existed between the crops. However, it is significantly envisage that cassava being a long season crop with an earlier slow growth rate allows it to recover from competitive effects. The slightly increasing trend obtained for ATER might be attributed to the fact that, both crops have different peak of nutrient demands (Table 4.17b).

Results indicated significant effect on cassava when intercropped was in association with cowpea, soybean and maize. Generally LER doesn"t take the duration of the crops in the field into consideration. It is based on the harvested proportion of the component crops. However, it is observed that the choice of sole cropped yield for standardizing crop in mixture yield in the estimation of LER is not clear (Willey, 1978). Therefore ATER provides more realistic comparison of the yield advantage in terms of variation by the component crops of different intercropping systems (Aasim *et al*., 2008).

Table 4.17a: Effect of various cropping systems on the area time equivalent ratio (ATER) of cassava in association of cowpea, soybean and maize

$$\mathit{Calculation\ of\ ATER} = \frac{\left[\left(\frac{Ya}{Sa}\right)Ta + \left(\frac{Yb}{Sb}\right)Tb\right]}{T}$$

$$\mathit{ATER\ Cassava}/\text{cowpea} = \frac{\left[\left(\frac{36.1}{28}\right)365 + \left(\frac{0.387}{0.55}\right)65\right]}{365} = 1.4$$

$$\mathit{ATER\ Cassava}/\text{soybean} = \frac{\left[\left(\frac{26}{28}\right)365 + \left(\frac{0.388}{0.75}\right)65\right]}{365} = 1.1$$

$$\mathit{ATER\ Cassava}/\text{maize} = \frac{\left[\left(\frac{29.7}{28}\right)365 + \left(\frac{1.461}{1.779}\right)120\right]}{365} = 1.5$$

(Yields in tons)

Table 4.17b: Effect of cropping systems on the area time equivalent ratio

Treatment	ATER
Cassava/ cowpea	1.4
Cassava/soybean	1.1
Cassava/maize	1.5

General interpretation of ATER:

ATER > 1 implies yield advantage in both time and land utilized

ATER = one or ATER < 1 implies no effect of intercropping

CHAPTER FIVE

DISCUSSION

5.1 Effect of intercropping on height of maize

Maize plant height at 1 MAP was greater in the intercrop than in the sole cropping. This could be probably due to competition for available resources especially solar radiation in the intercrop, which made the intercrop maize to direct assimilates for increase in height. Adeniyan (2014) found that intercropping of cassava and maize had significant effect on plant height of the cassava due to above ground competition.. Hassen *et al*. (1995) had reported that maize plant height was reduced by the use of different legumes in an intercrop system however, the present study conducted conforms to that of Adeniyan. It may be attributed to the fact that competition in the intercrop caused more assimilate to be directed to increase in height (Willey 1979; Vandermeer 1989).

Silwana and Lucas (2002) also, found that sole maize plant was taller than maize when intercropped with beans.

Number of leaves of maize in the intercrop was higher than the sole crop at 1 MAP, whereas at 3 MAP leaf production in the sole crop was greater. Initial competition that might have caused the production of taller plants also led to increased leaf production as the two processes go together. The greater leaf production by the sole maize at 3 MAP might be probably due to much reduction in available soil nutrients, hence the sole crop with fewer plants had more nutrients for greater leaf production.

5.2 Effect of intercropping on cassava growth

Plant height of cassava was generally greater in the intercrops. The tallest cassava plants were in the cassava/maize intercrop.

Maize and cassava plants are both tall plants, hence the intense competition, which led to rapid growth. Andrews and Karstan (1976) had observed intense competition for space and time for rapidly growing crops. Blaser and Brady (1990) also reported that growing grasses usually dominate associated legumes and take up larger amount of nutrient.

Canopy spread of cassava/maize intercrop was greater than that of the other intercrops and the sole cassava (Table 4.3). This may be due to intensive competition from maize. Leihner (1983) reported that cassava has a wide range of growth habits which may influence the amount of solar radiation interception during growth. These suggest that with high plant vigour and early branching cassava, there can be faster growth, and hence wider canopy spread.

5.3 Effect of cropping system on the growth of cowpea and soybean

In both crops, growth measured in terms of plant height and leaf production, was greater in the intercrops than the sole crops. (Table 4.5 and 4.6). As explained for maize competition for nutrients between the cassava and soybean and cowpea plants made the legumes to growth faster than the sole crops.

5.4 Effects of competition on crop yield

The result show significant variations in cob diameter of maize in cassava/maize intercrop (Table 4.8). An increasing trend obtained with the cob diameter of maize in association of cassava intercropping could be due to efficient utilization of available plant nutrients from different ecological niche for cob and grains development.

The results showed that cropping pattern did not significantly affect cob length, number of grains per cob and grain yield. Patra *et al.* (1999) reported increased number of cobs per plant and number of grains per cob due to maize legume intercropping system.

The result showed that intercropping pattern did not significantly affect cowpea mean 100 seed weight (Table 4.10). However, grain yield was greatly affected by cropping system as single culture yield was significantly higher than that of intercropping. Greater yield obtained in sole cropping system indicated reduction in competition for growth resources, especially nitrogen, as the cowpea was probably making use of fixed nitrogen more than soil nitrogen.

In soybean, mean 100 seed grain were significantly affected by cropping system, with the sole crop producing greater yield than the intercrop. Differences in plant population could have resulted in such high yield differences. Generally, legume, like soybean and cowpea are said to fix enough nitrogen for their use and even leave some N in the residue for succeeding crops (Fathiah, 2015 unpublished data; Sahabi 2015 unpublished data). The residual N in legumes haulms are capable of supporting maize crop (Mutaar, 2015 unpublished data).

Cassava root yield was rather greater in the intercrops than in the sole crop, except in the cassava/soybean intercrop (Table 4.14). The greatest root yield of cassava was measured in the cassava/cowpea intercrop (36.1 t/ha).

This may imply that cassava had competitive advantage over all the intercrops, therefore, getting the bulk of growth resources for greater root yield.

An added advantage gotten by the cassava crop was that following harvest, the residues of the other crops were left on the soil, which probably decomposed releasing organic matter and nutrients for the cassava crop. The latter advantage was not available to the sole crop. Interspecific competition may occur when two species are grown together.

The major factors that affect yield in relation to incident radiation in intercropping system are the amount of light intercepted and the efficiency with which intercepted light is converted to dry matter (Keating and Carberry 1993).

5.5 Effect of various cropping systems on land equivalent ratio

The study conducted shows that LERs values greater than one showing yield advantages of intercropping over sole culture. A yield advantage is obtained due to the development of both temporal and spatial complementary.LER values >1 indicates an advantage from intercropping in terms of the use of environmental resources for plant growth as compared with sole crops. When LER <1 resources are used more efficiently by sole crops than by the intercrops (Mariotti *et al.*, 2006; Kitonyo *et al.*, 2013 and Willey 1980).

The LERs of cowpea, soybean and maize respectively were 0.704, 0.517 and 0.821. The combined LERs was 2.042. The partial land equivalent ratio of cowpea (LER_c) were 34.5%, soybean (LERs) 25.3 % and maize (LERm) 40.2 % respectively obtained as fraction of the total LER of 2.042. These findings are also similar to (Workayehu , 2014) whose partial LER of maize and cowpea were 28.6 % and 15.8 % and Nyasasi (2014) whose study reveal LER of maize 51.6% and cowpea 48.4 %.

5.6 Effect of various cropping systems on competitive ratio

The competitive ratio (CR) obtained between the various intercropping system indicates that cassava was more productive than the rest of the crops in association.
These may be due to the architecture nature of the plant. The plant is capable of intercepting solar light in photosynthetic processing. The results indicated that cassava was slightly more competitive than cowpea, soybean and maize respectively. Table 4.16 shows the competitive nature when both crop were in association with cassava. In all the treatments cassava-soybean was highly competitive followed by cassava-cowpea.

The yield advantage of intercropped plots probably derived from cassava in interspecific competiveness proved cassava more competitive than cowpea, soybean and maize in the intercrop association. Studies have found that such competition lead to decreases or survival, growth or reproduction of at least one species (Vandermer 1989).

5.7 Effect of various cropping systems on the area time equivalent ratio (ATER)

Oroka (2012) study reported that average LER and ATER indicated 39 % to 81 % land utilization efficiency. This study showed that ATER was of great significant in terms of area used and time, when cassava was in association with cowpea, soybean and maize. ATER greater than (1) unity indicates intercropping yield advantage of the study (Hiebsch, 1980)

Results indicated that among the crops studied there were efficient greater utilization of both area and time. All the treatment significantly performed well with cassava/maize obtained (1.5) ATER, followed by cassava/cowpea (1.4) and the least being cassava/soybean (1.1) Table 14.17b

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study showed that growth and yield of cassava was affected by intercropping. Indeed, in some aspects the growth and yield was enhanced.

Among the three crops used as the intercrop, maize could be described as the best intercrop for cassava. This is because maize yield in the intercrop of 1.4 t/ha is comparable to average yield of maize obtain by most farmers. Additionally, maize yield in the maize/cassava intercrop was the greatest. The Land equivalent ratios of cassava/cowpea (0.704) and cassava/maize (0.821) intercrop were profitable, whilst cassava/soybean was not (0.517)

Area Time Equivalent Ratio (ATER) showed efficient land and time utilization for all the treatment studied (cassava/maize, cassava/cowpea and cassava/soybean) recorded the following value of 1.5, 1.4 and 1.1 respectively.

Finally, the competitive ratio showed that cassava was the most competitive among the four crops studied.

6.2 Recommendation

Since cassava intercrop growth and yield was better than the sole crop, it is recommended for farmers to do intercropping always in cassava production especially with maize.

It is recommended that, nodule counts in legumes used for the intercropped be taken into consideration in further studies in determming the reasons accounting for such yield differences.

Further studies should be done on cassava/soybean intercrop to verify results.

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