UNIVERSITY OF CAPE COAST

# EFFECT OF CASSAVA-LEGUME INTERCROPPING ALTERNATIVES ON CROP YIELDS AND SOIL PROPERTIES IN TWO AGRO-ECOLOGICAL ZONES OF GHANA

MARCUS TOBODAWOLO JONES

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BY

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Thesis submitted to the Department of Crop Science of the School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Doctor of Philosophy degree in Agronomy

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## DECLARATION

### Candidate's Declaration

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

Candidate's Signature:................................................... Date:..........................

Name: Marcus Tobodawolo Jones

### Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................. Date:........................

Name: Prof. Jonathan Padi Tetteh

Co-Supervisor's Signature: .......................................... Date:........................

Name: Dr. Roland Nuhu Issaka

# ABSTRACT

The research was carried out in two locations namely: Soil Research Institute, Kwadaso and Wenchi Agri. Research Institute, Wenchi. The experiment was laid out in randomized complete block design (RCBD) with three replications. Treatments in the first and second trials consisted of two factors: three levels of fertilizer (0-15-30 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$,), and four cassava based cropping systems. The behaviour of component crops in three row arrangements was evaluated in the third trial. Root yield was significantly affected by cropping systems at Kwadaso while fertilizer effect on root yield was observed at Wenchi. Cassava-groundnut intercrop gave the highest root yield of 70.2 t/ha at Kwadaso. The highest root yield (34.6 t/ha) at Wenchi was reported in plots treated with 15 N-$P_2O_5$-$K_2O$ k/g. The study showed higher increased in organic carbon by 39 -97% at Kwadaso and Wenchi. Total soil nitrogen decreased by 16.7%, available phosphorus by 70.8% and exchangeable potassium by 20% at Kwadaso. Increase in soil total nitrogen was reported at Wenchi. Exchangeable potassium decreased by 30% under cassava-soybean +15 N-$P_2O_5$-$K_2O$ kg/ha. Cassava showed higher values of aggressivity (1.8), relative crowding coefficient (57.4) and competitive ratio (21.4) in cassava-cowpea 2:1, cassava-soybean 1:1, and cassava-cowpea 2:1 intercropping system while cowpea and groundnut showed higher values of 0.5 and 0.6 for aggressivity. In the study, intercropping system gave higher land equivalent ratio (LER). Furthermore, cassava was more productive in terms of competitive ratio when it was in association with cowpea, soybean and groundnut.

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# DEDICATION

To my dear wife and children for their love and enormous support

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| | |
|---|---|
| A | Aggressivity |
| ANOVA | Analysis of Variance |
| $\mathrm{Cmol_0\ kg^{-1}}$ | Centimeter per kilogram |
| CR | Competitive Ratio |
| DM | Dry Matter Content |
| FAO | Food and Agricultural Organization |
| g | Gram |
| ha | Hectare |
| IFAD | International Funds for Agricultural Development |
| IITA | International Institute for Tropical Agriculture |
| Kg | Kilogram |
| LAI | Leaf Area Index |
| LER | Land Equivalent Ratio |
| MAP | Month after Planting |
| MoFA | Ministry of Food and Agriculture |
| t /ha | Tonne per hectare |
| UNEP | United Nation Environment Program |
| WAP | Week after Planting |

# CHAPTER ONE

# INTRODUCTION

## Background to the Study

The Rainforest and Forest Transitional agro-ecological zones of Ghana have good potential for farming. They receive relatively higher rainfall compared to other regions. They also have large urban centers that create high demand for food crop produce like cassava. Soil fertility decline is a major problem confronting crop production in Ghana. This is caused by crop nutrient removal and losses through soil erosion. Consequently, most of the soils are poor in the essential plant nutrients required for optimum crop growth leading to low crop yield(Adjei-Nsiah & Issaka, 2013). The often-low yield syndrome by virtue of the decline in soil fertility status thus renders many cropping systems unproductive.

In Ghana, one way to satisfy the increasing demand for food is through improvement of land productivity for both crop and livestock. Introducing improved cropping systems is particularly important since improved productivity provides not only more food but also income (FAO, 1995). Production of staple food crops, such as cassava, rice and maize, to feed the increasing population has become a major challenge for many developing countries. To cope with these problems, strategic management of both the soil environment and crop productivity needs to be considered.

## Cropping Systems

Cropping systems in Ghana have greater influence on soil fertility status. Intensification and diversification of cropping systems is reported to have pronounced impact on soil physical, chemical, and microbiological characteristics(Grant, Hargrave, & Macpherson, 2002).Cassava and maize are among the major staples grown in Ghana while cowpea (*Vigna unguiculata*), soybean (*Glycine max*), and groundnut (*Arachis hypogea)*are the main pulse crops grown in the country. Cassava (*Manihot esculenta*) is the second staple crop and is widely grown because of its low input requirements. The crop is also known for its adaptability to poor soils and erratic rainfall in the regions.

Intercropping maize and cassava is a common practice. Maize is planted first at the onset of the rains, while cassava is planted four weeks later after the first weeding. Cassava yields range from 5-15 t $ha^{-1}$ for sole crops but consistently less when planted as a relay crop at low densities (FAO & IFAD, 2005). This could suggest that yields are too low to satisfy food requirements in most households. Farming systems are heavily labour intensive with low inputs and risk adverse practices. Generally, farmers evolved cropping systems in the form of crop mixtures and rotations suitable for the various agro-ecological zones in which they operate, usually in the following pattern: Maize-legume (cowpea/Soybean), and maize/cassava(FAO & IFAD, 2005).It is therefore necessary to focus on making increased and sustained cassava yields in small-holder farmers' farm and thereby improving agronomic efficiency of inorganic fertilizer use in cassava-legume intercropping systems.

## Statement of the Problem

For small-scale farmers in developing countries, low land productivity is mainly due to low soil fertility and nutrient depletion that continue to present a major problem to achieving needed yields (Bekunda, Sanginga, & Woomer, 2010). In Ghana, one way small-scale farmers have been addressing the problem of soil infertility is by leaving the land to lie fallow; this is no longer applicable due to the continue increase in population. Farmers barely apply fertilizer owing to the high cost associated with synthetic fertilizers, contributing to the decline in yield and fertility status (Adjei-Nsiah & Issaka, 2013). Soil fertility is a major constrain for small holder farmers engaged in cassava production, owing to the limited use of organic and inorganic inputs(Bekunda et al., 2010). Integrated Soil Fertility Management (ISFM) targeting the agronomic efficiency through the combined use of organic and inorganic inputs has been recommended for sustainable crop production improvement in Africa (Vanlauwe et al., 2014).

Legume intercropping for instance has been adopted in tropical farming systems as a potential technology for improving smallholder food crop production (Ngwira et al., 2012). However, small-holder farmers in Ghana, like in many developing countries, are still faced with challenges in adopting legume intercropping systems solely targeting fertility improvement with little or no immediate economic returns to the farmer(Adediran, Akande, & Oluwatoyinbo, 2004). Agronomic investigations are needed to develop appropriate systems of soil fertility maintenance and crop yield improvement especially in cassava based cropping systems. Research has suggested the need to assess the potential of grain legumes intercrop with staple food crops, as alternatives to crop yield and soil properties improvement in the regions (Tonitto, David, & Drinkwater, 2006).

Intensive agriculture with limited use of inputs such as organic and inorganic fertilizer is a major cause of declining soil fertility in cassava production systems. This leads to poor cassava yield in Ghana. The study was to address the problem by investigating cassava-legume intercropping alternatives in two agro-ecological zones of Ghana.

## Objectives

The main objective of this study was to examine the effect of cassava-legume intercrops on the growth and root yield of cassava and companion crops and its impact on soil properties.

Specific objectives were as follows:

- i. To evaluate the effects of fertilizer and cassava-legume cropping systems on root and grain yields in two agro-ecological zones of Ghana.
- ii. To determine the effect of cassava-legume intercropping on soil physical and chemical properties in two agro-ecological zones of Ghana
- iii. To evaluate the effect of row arrangements on competitive behavior of component crops in cassava-legume intercrop.

# CHAPTER TWO

# LITERATURE REVIEW

## Overview of the Study

Decline in soil fertility accounts for the reduction in per capita food production in sub-Saharan Africa (Heerink, 2005). Soil fertility in real term, is the ability of the soil to supply nutrients for plant growth (Fred, 2013). The fertility of the soil plays major role in the productivity of cropping system. Decline in soil fertility has often threatened food security and abject poverty in developing countries (Ranamukhaarachchi, Mizanur, & Begum, 2005).

Studies have shown that during the last 30 years an average of 660 kg N $ha^{-1}$, 75 kg P $ha^{-1}$, and 450 kg K $ha^{-1}$have been depleted from the soils in nearly 200 million ha of cultivated land in several African countries (Gregory & Bumb, 2006). According toAyuke et al.,(2011), modern agricultural systems have resulted to progressive depletion of soil fertility due to reduction in soil organic matter. The use of legumes in cropping systems with non-legume crops will help restore soil productivity (Luce et al., 2015).Chikowo, Zingore, Snapp, and Johnston ( 2014) found that soil fertility maintenance approaches, such as bush fallow, legume intercropping and mixed crop-livestock farming were not capable of adjusting quickly enough to rapid population growth leading to reduction in farm size and soil fertility. Soil fertility restoration in small-holder farms should be considered as an investment in Sub-Saharan Africa(Omotayo & Chukwuka, 2009).

## Cassava

Cassava is a tuberous crop that produces long and tapered storage roots that are a major source of carbohydrates. Depending on the variety and growing conditions, these large storage roots are harvested from about 6-12 months after planting. Cassava can remain in the soil for one to two years without rotting especially so when under drought conditions (Hidoto & Loha, 2013). During its growth, the cassava develops alternating periods of vegetative growth and carbohydrate storage in its roots(El-Sharkawy, 2006).

Under favorable conditions, the photosynthesis process can contribute in plant growth after the true leaf appears at about one month after plantingand most of the leaves and stems develop in about three to six months after planting(Gan & Amasino, 1997). Since the leaves can intercept most of light incidence during the first three months after planting, maximum canopy size may be reached at six months after planting (Cock, 1979). The roots can absorb water and nutrients in the soil at one month after planting and initiation of storage roots take place when few fibrous roots become storage roots in about two to six months after planting (Howeler, 2001). Within six to ten months after planting, carbohydrate storage from leaves to roots may occur(John & Imas, 2013). Cassavacan be grown in a wide range of altitude and rainfall conditions from less than 600 mm in unimodal rainfall areas to above 2000 mm in bimodal rain fall zones (Chipeta, Shanahan, Melis, Sibiya, & Benesi, 2016). Howeler (1981) reported that the cassava crop can withstand low soil pH and high concentration exchangeable aluminum; moreover, it can withstand low concentration of phosphorus (P) due to its association with mychorrhiza fungi in the soil that can increase the uptake and transport of phosphorus to the roots and increase the explored soil volume.

Cassava is a crop that is suited for poor soils because it has a potential to produce reasonably good yields on eroded and degraded soils. Despite being a major staple food crop in Ghana, cassava serves as a major source of income for farmers and processors. Regardless of its role in the national economy, cassava production has not been promoted to any satisfactory extend with the belief that cassava depletes the soil(Adjei-Nsiah, 2010). This perception which has been arguably based on the ability of the cassava crop to grow on depleted soils where other crops would fail (Fermont, van Asten, & Giller, 2008) is however, contrary to perception by farmers in some parts of Ghana(Adjei-Nsiah & Issaka, 2013). According to MOFA (2012), cassava covers about 21.68% of the total land areas grown to food crops and further indicated that the area cropped to cassava increased from an average of 577,100 ha in the year1995 to 889,364 ha in 2011.

It is generally assumed that Sub-Saharan Africa produces about half of the total world production of cassava (FAOSTAT, 2004), however, average root yield ranged from 50 and 66% which is far lower than that of Asia and Latin America (Howeler, 1991). Most cassava growers in Africa are resource poor and in most cases, they rarely apply fertilizer to cassava (Sanginga & Woomer, 2009). Since inorganic fertilizers are scarce and expensive agricultural inputs for small-holder farmers, this has led to poor adoption(Nambiro & Okoth, 2013). Moreover, due to increasing rates of population growth, intensive agriculture system with limited soil fertility replenishment is practiced in most African countries including Ghana (UNEP, 2000). This has resulted, to further decrease in productivity in the cassava based farming system in most African countries. Integrated soil fertility management (ISFM) has a potential to move alternative cassava production options. This has been reported as the underlying technical framework especially for the sustainable intensification of production system in small-holder farms (Vanlauwe, 2012.). This is generally true for the agro-ecological zones across Ghana, particularly for dominant cassava based cropping systems. There is no doubt that sustainable crop production will therefore require careful management of all nutrient sources available in a farm, particularly for cassava based cropping systems.

### Cowpea

Cowpea (*Vigna unguiculata*) belongs to the family Fabaceae. It is a rustic plant, tolerant to the water regime especially in the semiarid region and under-demanding when it comes to soil fertility (Ribeiro et al., 2013). The grains contain up to about 25% percent protein and several other vitamins and minerals. It is grown mainly by small-scale farmers in developing countries where it is often intercropped with food crops as it tolerates shade, grows over the ground quickly, prevents erosion, and most importantly, replenishes low fertility soil when the roots are left to decay(Dugje, Omoigui, & Ekeleme, 2009)

On the basis of area cultivated (MOFA, 2012a) cowpea is the most important food legume grown in all agro-ecological zones in Ghana. The crop requires relatively less rainfall than most food crops. The age-long cropping system such as mixed or intercropping involving mostly cowpea has been intensified among small-scale farmers of the Savannah agro-ecological zone of Ghana (Kambiok, Safo, & Quansah, 2001) and the intention is to fix nitrogen that consequently reduces the mineral nitrogen requirements. Due to the importance of cowpea as an organic fertilizer and source of protein, it has received lots of attention by researchers. There are several accounts on efforts to increase cowpea grain yield by fertilizing poor soils, breeding and selecting varieties for high grain yields in intercropping systems with staple food crops (Isenmilla, Babalola, & Obigbesan, 1981; Terao, Singh, Shetty, & Blade, 1997). Generally, going beyond its importance as food and feed, the crop can be regarded as a pivot for sustainable farming practices especially in regions characterized by systems of farming that make limited use of purchased inputs such as inorganic fertilizer. It can be estimated that the cowpea crop can fix as much atmospheric nitrogen as 240 kg ha$^{-1}$ and make available about 60-70 kg N ha$^{-1}$ for the succeeding crops (Nederlof & Odonkor, 2006).

**Soybean**

Soybean (*Glycine max L.*) is an annual legume that belongs to the family *Fabaceae*. It is self pollinated with 2n = 40 chromosomes. It is one of the most important crops in world agriculture. The crop is unique among crop plants in a way that it supplies protein equal in quality to that from animal sources, one of the reasons for which it has been widely consumed(Aoyagi, 2015).

The role of soybeans for soil health and effect on crop productivity of subsequent crops has been investigated in a greater detail by scientists in the past two decades. Carsky, Abaidoo, & Dashiell, (1997) studied residual soybean nitrogen on subsequent maize grain yield under the prevailed situation of soybean residue removal at 10 sites in the Guinea savannah zone of Nigeria and reported that the yield increase following the medium duration soybean variety was similar to that from 40 kg N ha$^{-1}$applied four weeks after planting to maize preceded by maize.. . Nitrogen fixation and nitrogen inputs by different nodulating soybean lines were well studied in the southern Guinea savannah of Nigeria by Muhammad (2010). These workers reported that nitrogen derived from the atmosphere and nitrogen derived from the soil were the major sources of nitrogen accounting for 84 and 75 kg N $ha^{-1}$or 46% and 43% of the plant total nitrogen.

The combination of soybean to staple food crops in the cropping systems is becoming very popular among small-scale farmers in Ghana. This could be due to its nutritive and economic importance. For instance, Addo-Quaye, Darkwa, and Ocloo, (2011) concluded that soybean growing in associations with maize would provide high carbohydrate and protein diets for the resource poor farmers. One of the coping strategies adopted by farmers in the northern Guinea savannah zone of Ghana is intercropping legumes especially soybean, cowpea and groundnut with maize as a means of securing food in time of crop failure. However, it has been observed that farmers intercrop legumes with maize after the emergence of the cereal at their own convenient time

### Groundnut

Groundnut (*Arachis hypogea*)is predominantly grown in developing countries in Asia and Africa, where the crop finds the appropriate climates for optimum production(Baidu-Forson, Waliyar, & Ntare, 1997). It served as a major source of income for resource poor farmers, provides protein and other substantial nutritional qualities to human (Asibuo, Akromah, Adu-Dapaah, &Safo-Kantanka, 2008). Intercropping cassava with groundnut has been reported to benefit the use of space and reduce operating expenses per unit area (Nyi, 2014). However, giving the significant variation in branching habit of cassava, it is important to identify varieties that are best suited for intercropping especially with groundnut. In Ghana, intercropping cassava with groundnut is not a common practice by small-scale farmers; however, groundnut-maize intercrop has long been reported (Yea, 1968). It has reported that introducing groundnut in traditionally wide-spaced cassava planting would increase the production efficiency of cassava planted land as well as conserve soil moisture and fertility (Reddy & Willey, 1981). According Tarhalkar & Rao, (1975a) groundnut-cassava combination gave a double net income compared with the sole cassava planting. Contrary to this view, Tarhalkar and Rao (1975b) reported that when early sown groundnuts were intercropped with late-planted cassava, the yield of groundnuts was not seriously affected, but the yields of cassava were reduced to less than one-fifth of the sole crop. There is good evidence that groundnut-cassava intercropping can give a worthwhile yield advantages over sole cropping.

## Cropping Systems

FAO, (1995) described cropping systems as a community of plants which is managed by a farm unit to achieve various human goals, in which case the system of cropping is geared toward improving the fertility status of the soil so as to increase crop production. Okigbo (1978) labeled it as a crop production system that consist of the cropping pattern in terms of crop combination, spatial arrangement and sequences of cropping in addition to the resources and input management and technology involved in the production of the desired products.

The most favorable cropping environments are found in the tropics where rainfall is sufficient; crops can be grown all year round, rather than only in the warm seasons as in temperate regions. And yet despite these natural advantages, yield in tropical cropping systems are pitifully low.

Long and short fallows are two major fallow systems widely practiced in tropical Africa. Due to the alarming population growth, crop production under long fallow system has drastically declined in Africa. Soil fertility is a subject of importance in a discussion of expanding staple food crop production in Africa. The case in Ghana is no exception where 60% of the population makes their living from subsistence farming with an average of 27% living in extreme poverty (MOFA, 2012) Initially, farmers used to replenish soil nutrients by practicing shifting cultivation or land rotation but this is no longer possible due to increase in population growth. In Ghana for instance, the rapid increase in the population mount intense pressure on arable land, the practice of shifting cultivation is no longer sustainable (Issaka, 2012).

The unpredictability of climatic factors and the lack of nutrients for plant growth in many soils, limit crop production in tropical cropping systems (Ogle, Breidt, & Paustian, 2005). While it is true there are limited options to modify the climate, various approaches can be used to solve the problem of soil fertility. An outstanding solution is to import nutrients in the form of mineral fertilizers but for a variety of social, economic, and political reasons this is mostly difficult, especially in Africa (Giller, 2001).

Among the numerous cropping systems practiced in Ghana, crop rotation, continuous cropping and bush fallow, and various forms of intercropping are among the most dominant. These cropping systems, however, differ from one land use system to the other (NSFMAP, 1998). Given the wide spread prevalence of nutrient stress worldwide, a thorough understanding of acquisition, utilization, and recycling of both organic and mineral forms of nutrient is essential (Arihara, 2000).

### Crop rotation

The benefit of crop rotation is to increase yields and productivity, improve soil fertility and soil physical properties, reduction in weeds, diseases and insect pest population, and improved farm income (Oswald & Ransom, 2001). Crop rotation entails the growing of different crops in sequence on the same plot of land – changing the type of crops growing in the field each cropping season, for instance, as practiced in the south of Ghana where a filed planted to maize in the major season and after harvest, the same field is cultivated to cowpea in the minor season of the year (Kombiok et al, 2005). Researchers have indicated that crop rotation, in conjunction with other fertility management practices, is fundamental to long-term agriculture productivity and sustainability(Kumar & Goh, 1999).

### Continuous cropping

Lands are cultivated year after year under continuous cropping system. The practice is commonplace where farming land is scarce due to the rapid increase in population. Studies have revealed that continuous cropping results in lower exchangeable Ca, K, Mg ( Juo, Franzeluebber, Dibris, & Ikhile, 1996), organic C, total N content and enzyme activities (Riffaldi Saviozzi, Levi- Minizi, & Mencheiit, 1994) and effective cation exchange capacity than those under natural bush and planted fallow. For instance, soil under continuous maize cultivation also results in soil acidification (Juo et al., 1996) compared with the fallow plots as depicted by lower pH values and greater exchangeable Al and Mn. In addition to soil acidification and depletion of soil

K, observed depletion of Zn, organic C and total N in soil under long - term cropping of peanut, soybean and maize in the summer, and wheat in the winter (Bell, Harch, and Bridge, 1995). In an experiment under continuous cropping of cassava, Hati et al., (2008) observed excessive decreased in soil available Zn and Cu with fertilizer treatment, while farmyard manure had the reverse effect.

## Intercropping

The existence of multiple cropping systems especially intercropping system involving major staple and leguminous crops among the small-scale farmers in West Africa has long been studied (Ogola, 2013). Although little is known about the first appearance of intercropped field, but according to historians (De Wet & Harlan, 1975), intercropping probably existed early in agriculture evolution but disappeared from many areas as a result of the advent of modern agriculture dominated by mechanization and specialization.

In most intercropping trials implemented in the sub-regions, there has been agronomic advantages in practice since the Land Equivalent Ratio (LER) has always been more than one (Kombiok et al., 2005). However, some advanced reasons for the persistence of this system of cropping is largely due to the uncertainty and instability of income, and unstable soil fertility maintenance (Kombiok & Elemo, 2009). Kombiok & Elemo, (2009)reported that intercropping cassava with grain legumes increased farmer’s net income; improved the soil and reduced weed and soil losses by erosion as compared to mono-cropping system. Sugawara & Nikaido (2014)observed that the presence of cassava in a forage legume intercropping system resulted in the negative soil nutrients balance, supporting the need to review nutrient replacement recommendation for cassava.

Intercropping systems are wide spread in tropical latitudes, and therefore interest in quantifying their potentials would be a great contribution towards food and income security. The term “Intercropping” refers to the practice of growing two or more crops simultaneously on the same plot of land (Polthanee, Wanapat, Wanapat, & Wachirapokorn, 2001). Under this system of farming, farmers manage more than one crop on the same field and at the same time. Farmers in Ghana have traditionally practiced intercropping by growing two or more component crops with no distinct row arrangement and low component crop densities. Though intercropping is popular due to acclaimed advantage of higher productivity compared to sole cropping, its practice in Ghana is characterized by the overused of low yielding local varieties (Ennin, Asafu-Agyei, & Dapaah, 1999). GGDP (1991) report indicated that in the Guinea Savannah agro-ecological zone, 88% of farmers intercropped cowpea with sorghum or millet, while 40% of farmers in the forest savannah transitional zone practiced intercropping cowpea with other staples.

The predominance of intercropping in lower rainfall high-risk areas leaves little doubt about the possibilities of improved stability in crop yield and income (Jodha, 1976). Over many generations, low-external-input farmers particularly in the tropics have learnt to manage and sustain their production systems without a substantial effect on the environmental resource base. The role of intercropping as a means to enhance agricultural production and productivity has become paramount since agricultural land is a diminishing quantum (Midmore, 1993). Greater nutrient uptake by intercropping has been shown by several workers, for example, N (Adu-Gyamfi, Ito, Yoneyama & Katayama, 1997; Sakala, 1998), K, Ca, and Mg (Dalal, 1974). This has very often been claimed as the basic cause to determine whether greater uptake was the cause of or the effect of greater yields. Apart from the possible differences in rooting pattern and vertical root distribution, the mechanisms by which nutrient uptake is increased are far from clear.

One possibility is that, even where growing periods are similar, component crops may have their peak demands for nutrients at different stages of growth, a temporal effect that may help to ensure that demand does not exceed the rate at which nutrients can be supplied (Alhassan, 2000). However, differences in competitive abilities of component crops for soil N may stimulate N fixation (Rerkasem, Rerkasem, Peoples, Herrige, & Bergerson, 1988).

### Cassava based intercropping systems

Cassava is intercropped with other staples in most traditional cropping systems in the sub-regions. Crop components in a cassava based intercropped system are usually short-season and early maturing and in most cases they include maize, sweet potatoes, cowpea, and cocoyam (IITA, 1987). Crop grown alone as companion crops to cassava varies from region to region, country to country and from locality to locality in Africa due to differences in agro-ecological conditions and socio-cultural practices (Hauser, Wairegi, Asadu, Asawalam, Jokthan, & Ugbe, 2014). The most common intercrop with cassava includes cassava-maize, cassava-legume, cassava-vegetable, and cassava-yam.

In Ghana for instance, intercropping cassava with maize is one of the most popular mixed cropping combination under rain-fed agriculture.Ibeawuchi (2007) reported that cassava/maize intercrop is productive and compatible simply because maize is a short season crop while cassava is a long duration crop.

In an experiment to evaluate the productivity of cassava-yam-maize in the rain forest zone of Nigeria, Wallis (1997) showed that by intercropping, the farmer can obtain the same yield as in sole cropping cassava, yam, or maize and still have two years average of 45-67 percent more land available for other purposes. However, Ibeawuchi (2007) reported a significant yield decrease for cassava in a cassava-melon, cassava-maize intercropping experiments. With the increasing length of the cultivation period, and declining soil fertility, cassava is the predominant staple crop in many regions of the rainforest and Guinea Savannah, replacing especially other root and tuber crops like cocoyam and yam. Although cassava is most common in the forest region and Guinea savannah, cassava based cropping systems are mainly found on poor soil of the coastal belt where food crops other than cassava hardly give satisfactory yield (Kurt, 1984).

Cassava based farming systems are particularly prevalent as cassava is a major staple widely grown in most sub-Saharan African countries. The crop is widely spaced, and is often intercropped with short duration crops. However, among the intercrops, legumes have been considered to be compatible for intercropping with cassava as they are capable of supplying sustainable amount of nitrogen (N) into lower input agro-ecosystem (Polthanee et al., 2001). Leguminous crops are well suited for cassava in terms of nutrient demands since they need mostly phosphorus (P) and can get some required N from the nitrogen fixation through soil bacteria rhizobia in their root nodules while cassava extract more potassium (K) for storage root production and N for leaf production (Carsky & Toukourou, 2004; Howeler, 2002; Giller, 2001). Howeler, Cadavid, & Burckhardt, (1982)reported that intercropping cassava with legumes could increase land equivalence ratio as compared to the sole crop.Ezumah & Federer (1995)confirmed that land equivalent ratios were increased by 50% to 73% in cassava-cowpea intercrop and 10-58% in cassava –soybean intercrop. However, several authors have reported that intercropping cassava with legume crops did not show a significant effect on cassava yield relative to pure cassava cropping systems (Njoku, 2008;Zinsou, Wydra, Ahohuendo, & Hau, 2004).

Farmers in Ghana (Fining et al., 2009) allot optimum space to cassava as a major economic crop in intercropping systems. In the early growth stage, crops with relatively lower monetary value are intercropped to complement the utilization of growth resources. Although the overall productivity of an intercropping system can be greater, productivity of component crops can be influenced by the soil type or climatic conditions or both (Fukai & Trenbath, 1993). Useful crop improvement programme under cassava based intercropping system will require understanding the effect of soil and climatic conditions on yield components of the system.

Cassava is an ideal crop for intercropping since it is widely spaced and slow in its initial growth, especially during the first 100 days(Suja, Sreekumar, John, & Sundaresan, 2010; Polthanee, Wanapat, Wanapat, & Wachirapokorn, 2007). In humid and sub-humid tropics, intercropping cassava with legume is widely practiced to reduce soil erosion, nutrient leaching, soil fertility depletion, and to control weeds (Harms, 2011). However, many researchers have argued that intercropping systems increase competition for water, light, and nutrients (Islami et al., 2011)

**Cassava-grain legume intercropping systems**

Several grain legumes, including cowpea, groundnut, Soybean are selected as companion crops in many intercropping practices in the tropics. Studies concluded that cassava storage root yields were higher when intercropped with groundnut, relative to other intercropping cassava with cowpea and Soybean, (Leihner, 1983, Ennin & Dapaah, 2008) Soybean is a relatively specific host and does not nodulate when growing in the field for the first time in many part of Africa (Giller, 2001).

Cassava-legume intercropping system has the potential to address soil nutrient depletion on smallholder farms (Sanginga &Woomer, 2009). The legumes play an important role in nitrogen fixation (Mark B. Peoples & Craswell, 1992). According to Sanginga and Woomer (2009) intercropping grain legumes with staple food crops help maintain and improve soil fertility, because crops such as cowpea, soybean, and groundnuts accumulate from 80 to 350 kg nitrogen (N) $ha^{-1}$ (Peoples &Craswell, 1992). For instance, soybean can positively contribute to soil health, human nutrition and health, livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services, than many other leguminous grain crops (Mark B. Peoples & Craswell, 1992). According to Willey (1979) for plants to derive benefits from intercropping, inter specific competition for growth factors should be lower than intra specific competition in single stands. In a legume-cassava combination, the legume may suffer from competition under high soil fertility conditions. On the other hand, the growth and yield of the cassava may be reduced under low soil fertility conditions where the legume has competitive advantage. According Ikeorgu and Odurukwe (1990), groundnut plant has a universal ability to utilize soil nutrients that are relatively unavailable to other crops and is very effective in extracting nutrients from sandy soils of low nutrient supply.

In Ghana, Cassava is found in variety of crop production systems and performs well under various levels of managements. Incorporating grain legumes into cassava based cropping system may be the most desirable strategy to enchasing protein intake and nutritional security for resource poor farmers whose staple is purely cassava. Cassava is a staple for more than 80 million people living in developing countries and has the potential to replace expensive imported raw materials such as starch and wheat flour for various African Industries (Cook, 1979). Despite individual yield reduction, incorporating grain legumes into cassava based cropping system could enhance the overall productivity of the system (Ogola and Magongwa, 2013).

### Role and Dynamics of Essential Plant Nutrients in Cropping Systems

The soil supplies 13 out of the 16 elements that are known to be essential for crop growth of which N, P and K are the most commonly deficient nutrients in agricultural soils (Follett, Gupta, & Hunt, 1987). Each of these nutrients plays a remarkable role in plant nutrition, deficiency of which produces either visible or hidden symptoms.

## Nitrogen

Nitrogen (N) is the nutrient that is most frequently limiting to crop production and the nutrient applied in the greatest amounts (Campbell, 1990). It is a part of all plant proteins and a component of DNA and RNA. Nitrogen is required for assurance of optimum crop quality as protein content of crops is directly related to N supply(Reitzer, 2003). An efficient cropping system will attempt to balance crop demands for N with timing and rate of N supply so that crop yield is optimized while N is neither over-depleted from the soil nor accumulated in quantities that results in the contamination of ground waters or surface waters (Grant et al., 2002). As crop production increases, so does N removal from the system (Peterson, 1996).

Therefore, total nutrient removal with continuous cropping will be substantially higher than with a fallow system.Kolberg, Kitchen, Westfall, and Peterson (1996) showed that inclusion of corn in a more intensive winter wheat-corn-fallow rotation led to greater depletion of soil N than did a winter wheat-fallow rotation, particularly at lower rates of applied N. With increased nutrient removal, responses to fertilizer application become more likely (Campbell, Lafond, Leyshon, Zentner, & Janzen, 1991). For example, changing from a wheat-fallow to a wheat-corn-fallow rotation required a 44 % increase in N fertilizer inputs (Kolberg et al., 1996). Therefore, in intensive cropping systems, N fertilization becomes increasingly important. Ranamukhaarachchi et al. (2005) studied soil N dynamics in highlands and medium highlands of Bangladesh and indicated that there was no significant effect of cropping systems on soil N. according to them, the low N content of the soils after the study was due particularly to low organic matter content and partially to losses. Nitrogen losses mainly occur through leaching, surface runoff, denitrification and ammonia volatilization (Cai, Chen, Pacholski, Fan, & Zhu, 2002). Crop uptake of N is relatively inefficient and often results in average losses of 50% because of leaching, volatilization or denitrification (Zublena, 1997).

### Phosphorus

Phosphorus (P) is involved in energy dynamics of plants (Zublena, 1997). Without it, plants cannot convert solar energy into the chemical energy needed for the synthesis of sugars, starches and proteins. Phosphorus, nitrogen and other nutrients need to be available to the crop in adequate amount to optimize crop yield and quality and efficiency of crop production (Halvorson and Black, 1985).

Cropping intensification and diversification will influence both P supply and demand in cropping systems (Grant et al., 2002). Phosphorus dynamics can be affected by cropping intensification and diversification. Intensified cropping in the absence of P inputs from fertilizer or organic amendments will result in depletion of soil phosphorus. Mckenzie, Stewart, Dormaar, and Schaalje (1992) evaluated the effect of cropping system and fertilizer management on P in two long-term rotation studies in Alberta. They found that without fertilizer application, continuous cropping resulted in the greatest reduction of almost all soil organic and inorganic P pools. However, when continuous cropping was coupled with the addition of N and P fertilizers, there was a positive effect of cropping on P availability (Grant et al., 2002). Bowman and Halvorson (1997) reported increases in P availability under a continuous cropping system compared with wheat-fallow systems even though P inputs were generally greater in the latter system. The increased P availability was attributed to redistribution of soil P from lower depths through biocycling in residue and litter production. The type of crop grown will also influence P depletion because crops differ in their yield potential and in the amount of P removed in the harvested portion.Increasing crop yield will increase P removal, though it may not be as great an impact on the P fertilizer requirements as there is with N because the amount of P removed by crops is small relative to the total P in most soils. For example, in the Brown soil zone in India, the soil available P has been constant over 30 years of cropping (Roberts, Zentner, and Campbell. 1999). The preceding crop may have an important influence on P nutrition of crops due to its effect on mychorrizal activity. The extended hyphae of the fungi can penetrate into the soil considerably further than the root hairs of the plant; thereby increasing the zone of absorption of immobile nutrients such as P. Mychorrizal interactions are important for uptake of P and Zn particularly under low fertility conditions (Kucey and Paul, 1983). Severe early growth problems can occur due to P deficiency when corn is planted on fields that were fallowed the previous year (O'Halloram, Miller, and Arnold. 1986). Vivekanandan and Fixen (1991) reported that early dry matter production and P uptake were higher in a ridge planted corn-soybean rotation than in a mouldboard ploughed corn-fallow system, where no P fertilizer was added.Rao, Barrios, Amezquita, Friesen, Thomas, Oberson, and Singh (2005) indicated that knowledge of P dynamics in the soil - plant system, and especially of the short and long-term fate of P fertilizer management practices, is essential for the sustainable management of tropical agro-ecosystem. Although much of the phosphorus added to the soil may be fixed by chemical reactions with Fe, Al and Ca and becomes unavailable for crop uptake, the study of its dynamics is still necessary to enhance efficient management.

### Potassium

With the exceptionof nitrogen, potassium is a mineral nutrient plants require in the largest amounts (Marschner, 1995). Potassium (K) is involved in photosynthesis, sugar transport, water and nutrient movement, as well as protein synthesis and starch formation (Zublena, 1997). It also helps to improve disease resistance, tolerance to water stress, winter hardiness, tolerance to plant pests and uptake efficiency of other nutrients.Ranamukhaarachchi et al. (2005) studied soil fertility and land productivity under different cropping systems and observed that the cropping systems had no significant effects on K content in soil in both highlands and medium highlands.Srinivasa, Anand, Subba, and Raja. (1999) reported a significant decline in K release due to continuous cropping. Recycling of crop residues or applications of high dose K fertilizer may provide a long-term sustainability to cropping systems (Singh & Awasthi, 1978). According to Zublena (1997), K removal by crops under good growing conditions is usually high and is often three to four times that of P and is equal to that of N. In many cases where levels of soluble K in the soil are high, plants tend to take up more K than they really need (Zublena,). However, it is well-known that the availability of K to plants does not only depend on the size of the available pool in the soil, but also on the transport of K from soil solution to the root zone and from the root zone into plant roots (Barber, 1995).

In Ghana, the intensity of cropping systems is presently not high enough to cause widespread K deficiency under the smallholder-farming situation (NSFMAP, 1998). The amount of K released from the ash after burning is adequate for the yield levels for the limited period of cropping. The picture, however, will change drastically when sedentary agriculture becomes the pattern of crop production and production is intensified (NSFMAP). Under such a circumstance, K management will become very important in sustaining or increasing crop yield. Proper K management requires a thorough understanding of soil K behaviour and of the various K inputs and outputs of cropping systems (Hoa, 2002).

### Exchangeable Calcium and Magnesium

Calcium (Ca) is one of the essential elements obtained from the soil by plants and used in relatively large quantities. It is a macronutrient and also a secondary element since it is usually added to the soil indirectly during the application of materials containing the primary fertilizer elements - NPK (Hesse, 1998). Magnesium (Mg) is an essential part of the chlorophyll molecule. It is also involved in energy metabolism in the plant and is required for protein formation (Zublena, 1997).According to Hesse (1998), Mg occurs in soil, principally in the clay minerals, being common in micas, vermiculites and chlorites. Welte and Werner (1963) investigated the uptake of Mg by plants as influenced by hydrogen, calcium and ammonium ions. They found that hydrogen ions suppressed Mg uptake most and with a strongly acid substrate, Mg deficiency could be remedied by applying Mg and raising the pH.Zublena (1997) stated that depletion of Ca and Mg reserve in the soil by crop removal is rarely a problem in limed soils because of the large quantity of these nutrients that are present in liming materials. However, some crops, such as peanuts, may require more Ca than the crops can remove.

Higher soil Ca and Mg levels have been reported in no tillage system compared with conventional tillage (Ferrer, 1984; Hargrove, Reid, and Gallaher, 1982) but Blevins et al. (1977) found no significant effects in exchangeable Ca under different tillage methods. Higher Ca and Mg contents were found in the oat/soybean soil surface compared to the oat/grain sorghum cropping systems (Ruben and Gallaher, 1976).

### Nitrogen Transfer from Legume to Non-Legume

The idea of intercropping root crop like cassava, with legume is based on the assumption that root crops can utilize nitrogen fixed by the legume. The legume may increase the supply of available nitrogen in the root medium, but it could also compete with the non-legume for the fixed nitrogen (Simpson, 1965). Bryan (1962) experimented nitrogen transfer between legume and non-legume plants and found that non-legume plants benefits more from the increase in nitrogen supply than it suffers from competition by the legume, and there is a net transfer of nitrogen to the non-legume. In general, legumes are weaker competitors for mineral N than many crops (Henzell and Vallis, 1977). According to Valis et al. (1967) when legumes are used as substitute for non-legumes in an area where the N supply is limiting, the remaining non-legumes are able to take up more mineral N per plant than they would in a pure stand of non-legumes, which is termed as the "N-sparing effect" of substituting nodulated legume for non-legume plants. In general, it is found that non-legume crops are unlikely to benefit from associated legumes sown at the same time unless the non-legume plants continue to take up N after the legume plants have begun to senesce and die. Thus, it seems that there may be two opposing considerations in the choice of the relative time of sowing legumes and non-legume crops in an intercrop. If the legume is sown early it may compete with the non-legume for soil mineral N but there could be an opportunity later for rapid and effective transfer of N to the non-legume companion crop.

However, if the legume is sown late, the non-legume will already have taken up soil mineral N but there will be little or no opportunity for N transfer immediately and some legume N may even be lost before another crop can use it (Henzell & Vallis, 1977). In many cases, non-legume crops may receive N fixed by legume crops while grown together or while grown after the legume crops(Whitney, 1977). Several researchers have pointed out two major pathways through which nitrogen could be transferred from leguminous to non-leguminous crops: 1) Above ground transfer including leaching of nitrogenous compounds from leaves by rain as well as decay of fallen leaves or other litter and 2) underground transfer through direct excretion of nitrogenous compounds from legume root systems and use by non-legume root systems, and decay of nodule and root tissue (Virtanen et al., 1937; Walker et al., 1954; Whitney & Kanehiro, 1967).

Research managed trials showed that leguminous plants were able to excrete N into the substrate in which they were growing and that the N may be utilized by associated non-leguminous plants (Virtanen et al., 1937). Similar results were reported by Wilson and wyss (1967); indicating N excretion in grain legumes and Vest (1971) also provided some evidence of N excretion in several experiments where non-nodulating soybeans, grown in t mixture with two nodulating cultivars, had higher yields, higher percent protein and larger seed size than the non-nodulating line grown in pure culture. In another experiment where nodulating and non-nodulating soybean isolines were grown in pure and mixed cultures, Burton et al. (l983) reported that the average performance of the non-nodulated component of the mixture was 38% greater than the average yield of the non-nodulated line in pure cultures, indicating that non-nodulated isolines benefited from nodulated isolines in mixed culture.

On the other hand, Singh, Tripathi, Negi (1974) established that yield and percent N of non-nodulating soybeans increased as the frequency of nodulating border rows increased in a mix of nodulating and non nodulating soybean, indicating the N release from nodulated plants to non-nodulated plants. Release of N from the legume and its transfer to an associated non-legume is significant only when vigorous legume growth occurs. This N transfer is more common in perennial than in annual legumes (Whitney, Koch, and Wacek, 1976). Seasonal conditions such as long days, low temperatures and shading seem to favor N excretion (Butler, Greenwood, and Soper, 1959). Carbon/nitrogen ratios have also been reported as a governing factor in N fixation and N excretion by legumes (Virtanen, 1947). Most of the experiments indicated that the transfer of N from living root system of legumes is only a small percentage of the total N fixed (Vallis, Haydock, Ross, and Henzell, 1967; Whitney and Kanehiro, 1967; Henzell and Vallis, 1977). The amounts of N turnover by the decomposition of sloughed nodules, root tissues and foliar residues are probably more important than the direct transfer of N between the legumes and non-legumes (Whitney, 1982). The availability of N from legume residues depends on the rate of the mineralization process.

The proportion of N released during decomposition of the residues is governed by the chemical composition of these residues, especially the N content, the manner in which the residues are returned to the soil, and the environmental conditions. The chemical composition of legume residues depends to a large extent on the proportion of different plant parts and their maturity (Henzell & Vallis, 1977). Amounts of N returned to the soil in the form of legume residues vary widely according to the legume yield and whether or not it is utilized for grain, forage, grazing or green manure. N content in grain legume residues may be lower than that in pasture legumes (Henzell & Vallis, 1977). Henzell and Vallis (1977) reported N-content ranges of 3-5% in tops and 2-4% in roots in some pastures legumes.

Hanway and Weber (1971) recorded 2% N in the fallen leaves from a mature soybean crop and 0.9% N in the stems and roots. Plant residues containing more than 1.8% N usually mineralize N immediately, and those with less than 1.2% N usually immobilize it temporarily (Schlichting, 1978). Part of the N in legume residues quickly becomes available for reuptake and the remaining N after the initial flush of mineralization becomes available only very slowly for later crops (Henzell & Vallis, 1977).Bartholomew (1965) estimated that about 60% of the N in legume residues is likely to be mineralized in time for the subsequent crop. The remainder is lost or is incorporated into the soil organic matter which may become slowly available for later crops. Henzell and Vallis (1977) reported that as much as 30% of the tropical legume residues were mineralized and taken up by the companion grass after 24 weeks. The rate of mineralization of plant materials also depends on the method of its application. Fresh plant material mineralizes at a faster rate than dried material (Fierer & Schimel, 2002) and buried residues decay at a faster rate than do surface residues (Moore, 1974).The mineralization process is affected by several other factors. Higher soil temperature enhances mineralization; higher soil moisture reduces mineralization cultivation may also enhance the rate of mineralization (Cassman & Munns, 1980).

Grass root extracts have been reported to suppress nitrifying bacteria (Theron, 1951), however, grass and legume root extracts have also been reported to increase the rates of N mineralization and nitrification (Odu &Akerle, 1973). Mineral N from decomposing plant material may also be lost from the soil in a solution or in a gas form by leaching, volatilization and denitrification (Bartholomew, 1965). In an experiment where crop residues were ploughed, N was subjected to a loss through plants uptake (Chen, Liu, Tian, Yan, & Zhang, 2014). Lees, Raun, & Johnson, (2000) have also shown the loss of N from plant residues of soybeans. Loss of nitrates by leaching may be minimized by growing deep-rooted crops like cassava, and the role of a deep-rooted crop in reducing losses of nitrate is further enhanced in intercropping systems (Ahlawat, Singh, & Saraf, 1981). Major losses of N are common from the N-fertilizer applied to the soil. Review by Allison (1966) indicated that average crop recovery is about 50% of the N applied. Other experiments (Soper et al., 1971; Toews and Soper, 1978) with barley have shown similar recovery (50%) from N fertilizers broadcasted. N recovery, however, was increased to 60% by band application of N fertilizers. The amount of N contribution from legume to an associated non-legume or to a subsequent crop depends on the N fixing ability and N requirements of the legume. The amount of N fixed is determined by many factors including plant species, plant density, climatic conditions effectiveness of bacterial strain, soil ph and nutrient status, and the amount of available N in soil (Allison, 1965).

The quantity of N fixed by legumes is varied in a wide range among leguminous crops. Several researches have reported varying among of N fixed by legumes from a few kilograms to 700 kg N ha-1 in a year (Jones, 1974; Graham and Hubbell, 1975). According to Nutman (1971), annual legumes seem to fix appreciably less N per year than perennial legumes due to a shorter growing season for annuals. In perennials at least one third of the fixed N is concentrated in the root mass, while in annual legumes, when ready for harvesting, most of the N assimilated from the atmosphere goes in the top portion of the plants (Sundara & Rao, 1975). Various estimates of amounts of N fixed by soybeans, cowpea, and groundnut have been reported. In several experiments, it has been reported that grain legumes fix about 84 kg N ha-1 (Weber, 1966), 93-160 kg N ha-1 (Vest, 1971), 148-163 kg N ha-1 (Weber et al., 1971), and 17-369 kg N ha-1 (Gomez and Zandstra, 1976). Schroder and Hinson (1974) studied the nodulating and nonnodulating soybeans grown in rotation with winter rye and in mixture with rye, and found that roots of nodulating soybeans left a considerable amount of N in the soil.

### Combined Application of Organic and Inorganic Inputs in Cassava Based Cropping Systems

Most commonly, organic and inorganic fertilizers are the two materials used for soil fertility improvement. Several researchers have reported that cassava extracts more potassium (K) than any other comparable crop, while also extracting significant amounts of nitrogen (N) and Phosphorus (Howeler, 1991; Islami et al., 2011). Various soil fertility management interventions have been tested, for instance, the use of mineral fertilizer in cassava based intercropping systems contributed to appreciable root yield of cassava up to 60 t/ha (Issaka, Buri, Asare, Senayah,& Essien, 2007). One notable constrains in Ghana, has always been the inability of small-holder farmers to purchase fertilizers inputs due to the high cost associated to these inputs(Kombiok et al., 2005). The cassava crop can tolerate harsh environmental conditions such as drought and survive fairly well in soil of low fertility. Several researchers have indicated that continuous cropping of cassava depletes the soil of essential nutrients (Howeler, 1991;Schulthess, Neuenschwander, & Gounou, 1997). Organic and inorganic inputs have long been proven as useful materials for soil fertility maintenance and yield improvement in agricultural systems.

Combining organic and mineral fertilizers has been shown to be a sound management principle for small-holder farmers in the tropics to sustain soil fertility and crop production (Vanlauwe & Zingore, 2011). This might be due to (i) inorganic fertilizer or organic inputs alone may not practically support sufficient amounts of nutrient for alleviating specific constraints to crop growth (Sanchez and Jama, 2002); (ii) the potential added benefits formed through positive interactions between organic and inorganic fertilizers in the short term (Place, Barrett, Ade Freeman, Ramisch, and Vanlauwe, 2003) and (iii) both organic and inorganic inputs play a major role in the long term agricultural sustainability (Vanlauwe et al., 2010). Fertilizer may respond differently in mono-crop systems than intercrop systems, while ideal rates of application for these systems still require investigation (Leihner, 1983). However, several researchers have reported that there are great benefits to intercropping systems of organic and inorganic soil fertility amendments.

In a long-term fertilizer experiment,Merck (2002)concluded that the use of organic and inorganic fertilizer improved soil nitrogen. It has been reported that cassava responds to the combined application of inorganic fertilizer and green manure (Pyper et. al., 2012).

**Nitrogen Mineralization**

Mineralization refers to the microbial transformation of an element from organic to its inorganic state. According to Gary (2001), the need to understand and explain the role of active C and N pools in cropping systems continues to be critical for predicting N mineralization and availability in cropping systems. Jarvis et al. (1996) stated that better quantification of the N mineralization contribution in cropping systems would help minimize N losses to the environment and allow more accurate recommendations for crop production. If N mineralization can be predicted more reliably, more precise management can be adopted so that supplemental N can be applied to optimize crop production without the risks of over application (Gary, 2001). The natural N supply for plants and microorganisms results mainly from the mineralization of organic compounds (Runge, 1983). This process occurs in twofold: ammonification and nitrification, which account for N availability to plants and microbes. The nitrogen available for crop growth after application is often estimated from the ammoniacal N plus a portion of the soil organic nitrogen (Sluijsmans and Kolenbrander, 1997). Snapp and Borden (2005) studied soil N dynamics in cereals and legumes cropping systems and observed that soil NO3 – levels increased gradually over time whereas the soil NH4 +_N pool size remained constant. In their study on mineralization, Das et al. (1997) observed that the lowest NH4+ and NO3- concentrations were obtained during the rainy season and the highest during the winter, with extractable NH4+ being always higher than extractable NO3-. In Ghana, Nye and Stephens (1962) observed a gradual increase of NO3- during the dry season and a more rapid increase as soon as the rains began. The NO3- levels fall during the rainy season and remain low until the beginning of the dry season. Sanchez et al. (2001) evaluated N mineralization potential for a long-term cropping system trial in southern Michigan and observed that cover crop with mixed quality residues was associated with approximately 30 % higher N mineralization over 70 days incubation compared to that associated with a monoculture cereal cover crop.

Many studies have focused on fates of N input during one or more growing seasons and many chemical and biological assays have been developed to predict N availability to crops (Bundy and Meisinger, 1994). However, less is known about the actual rates of short-term microbial biomass N transformations in systems that differ in C availability and soil N supplying capacity. Agricultural soils that differ in organic matter inputs would be expected to differ in rates of soil N transformations, competition for NH4+ by immobilizers and nitrifiers and fates of NO3- (Martin and Louise, 2003).

NH4+ has been found to be the preferred form of N for assimilation by microbes in many cultivated soils (Azam, Simmons, and Mulraney, 1993). Nevertheless, nitrification is often considered the major fate of NH4+ in agricultural soils (Robertson, 1997), where NH4+ is usually present in low concentrations.

In some agricultural soils, no NO3- immobilization has been observed (Shai and Norton, 2000); while in others NO3- immobilization was recorded after 1 - 4 weeks (Schimel, 1986) or several months (Kissel and Smith, 1978). Carbon inputs often increase NO3 – immobilization (Recous, Mary, and Faurie, 1990). Predicting the effect of management on residue N mineralization could enhance synchronization of N supply and crop demand. Environmental conditions, crop and soil management all influence the rate of N mineralization from indigenous soil N and added organic sources (Snapp and Borden, 2005). According to Gary (2001), soil N mineralization was greater where highly labile N sources such as manure or alfalfa residues were amended to soil. Empirical models have been used widely in literature to predict nitrogen mineralization under laboratory conditions. The use of these models aims to evaluate or predict observed phenomena or experimental data with the objective of helping the development of adequate soil management practices (Camargo et al., 1997

### Nodulation Ability of Grain Legumes in an Intercrop

The developing of nitrogen fixing nodules begins from symbiotic interactions between soil bacteria commonly known as rhizobia and the legume plants. This process in legumes provides a major conduit of available nitrogen into the biosphere. Nodulation is more specifically found in the

Genera *Azorhizobium*, *Allorhizobium*, *Bradyrhizobium*, *Mesorhizobium, Rhizobium* and *Sinorhizobium* (Kinkema, Scott, Peter, 2006)

N is a feature common to all legumes, which tend to differentiate them from most other families of plants. Although it has generally been assumed that these N-rich leaves are a consequence of $N_2$fixation, this is a feature found in all *caesalpinioid* legumes, including those that do not modulate(Sprent & James, 2007a). Despite some expensive survey of nodulation ability (Zahran, 1999) there are still an enormous number of legumes, particularly in the tropics, whose capacity to modulate have not been confirmed (Gage, 2004). The relevance of nodulation and nitrogen fixation to agriculture, natural ecosystems, and the global nitrogen cycle are indisputable (Graham & Vance, 2003). Legumes are cultivated on 12–15% of available arable land and constitute more than 25% of the world's primary crop production (Sprent & James, 2007b). They provide roughly 200 million tonnes of nitrogen per year, second only in importance to the *Gramineae* with respect to agricultural production (Roberts et al., 2013) The primary environmental condition that regulates nodulation in legumes is the availability of fixed nitrogen either as ammonia or nitrate in the soil (Peoples et al., 2001) this kind of environmental control prevents the plant from investing in nodule development under condition where nitrogen is not limiting (Dudley, Michener, & Lajtha, 1996).

Early efforts had focused on fertilizer trials instead of exploiting the potential of legumes to improve smallholder-farming systems, as practiced by traditional farmers. Not until recently, contemporary research efforts were directed toward the introduction of edible leguminous species into farming systems research to harness fertility potential with staple root crops like cassava as a based crop. Ibeawuchi et al. (2008) reported higher dry nodule weight in sole legume than in yam/cassava based cropping mixture and observed a further decrease with increasing number of crops in the mixture.

One of the problems usually observed in legume intercropping is shading of legumes by cereals. Shading decreases the availability of light to the legume and thus less photosynthates are available for the rhizobium to continue N fixation (Bethlenfalvay and Phillips, 1977; Eriksen and Whitney, 1982). Reduced nodulation and reduced nitrogen fixation in legume in cereal/legume intercropping has also been reported in soybean (Reddy and Chatterjee, 1973). Kitamura, Whitney, and Guevarra (1981) studied the competition between *Desmodium intortum* and *Setaria anceps* and reported that nodule numbers were depressed by both shoot and root competition but the legume plants were able to compensate by increases in nodule size and increases in acetylene reduction activity per unit of nodule weight (specific nitrogenase activity). Increase in nodule activity in soybean has been observed with up to 18% shading (Trang and Giddens, 1980) and with 20% shading (Wahua and Miller, 1978). Shading reduced the number of small-sized nodules, and increased the efficiency of bigger-sized nodules up to 20% shading then nodule activity rapidly declined with increasing shade. Studies by ICRISAT (1977) included the efficiency of nitrogen fixation in pigeon peas when interplanted with sorghum. Pigeon peas had better nodulation when the roots intermingled with those of intercropped sorghum. Thompson (1977) reported an apparent increase in nodule number and weight of soybeans growing with corn. He explained that the cereals depleted soil nitrogen, thus stimulating the nitrogen fixation by legumes.

## Cassava Litter and Benefit to Cropping Systems

Litter or litter fall is a dead plant material such as leaves, back, twigs, that have fallen to the ground. This dead organic material and its constituent nutrients are added to the top layer of soils commonly known as the litter layer (Lonsdale, 1988).It has been reported as an important source of organic matter and nutrients (Adjei-Nsiah, 2010). According to Howeler and Cadavid (1983) new leaf production is offset by leaf fall after the fourth month of growth. In the humid forest zone of In an on-farm experiment to estimate cassava leaf litter, Carsky & Toukourou, (2004b) estimated about 2 to 2.5 t ha $^{1}$ of fallen litter of cassava in nine months of growth.Horst, Kuhne, and Kang (1995) collected about 1.4 t ha $^{1}$ in un-amended plots and 3.1 t ha $^{1}$ in plots amended with NPK fertilizer in the sub-humid zone of southern Benin. This may partly explain why Poss, Fardeau, and Saragoni, (1997)observed higher than normal yields of maize immediately after a cassava crop in southern Togo. El-Sharkawy (2004) found up to 3.0 t ha $^{1}$ of cassava litter at harvest for four varieties grown for ten months in Colombia. The litter contained approximately 30 kg N, 2 kg P and 5 kg K ha 1. In an on-farm trial to estimate cassava litter fall in Benin, Carsky and Toukourou (2004) concluded that the amount of litter produced over the growing period can be increased by fertilizer application. They further showed that a good estimate of total litter DM can be made from the total dry matter (25 to 29%) when fresh root yield ranges from approximately 15 to 25 t ha$^{-1}$.

Cassava litter deposition offers a mulch soil-cover and may reduce soil erosion and also contribute to the recycling of substantial amount of nutrients removed from the soil. Adjei-Nsiah (2010) assumed that incorporating cassava stems, leaves and litter into the soil would greatly diminish total nutrient export and thus the requirement for fertilization. Subsequently, he reported significant differences among different cassava varieties with respect to litter production but did not record differences among varieties with regard to the amount of N returned to the soil. Due to the low cation exchange capacity (CEC) of major clays of most tropical soils, strategies to increase nutrient holding capacity of soils in tropical small-holder cropping systems are based on increasing the soil organic matter (SOM). This can be achieved by increasing inputs of organic materials to the soil and preventing excessively high rates of litter decomposition. The organic material inputs to a soil can be of plant (e.g. leaves, twigs, branches, stems, roots and root exudates of vegetation) or animal (e.g. excreta of farm animals, and exudates and dead bodies of soil micro-fauna such as earthworms, and microbes responsible for organic matter decomposition) origin. Similarly, cassava litter which is largely a buildup of leaves fallen from cassava, have been reported to contribute to soil N accumulation (Adjei-Nsiah, 2010). The cycles of carbon and of many macro and micronutrients are severely affected by changes in litter-fall input.

This is especially important in the tropics, where soils are naturally poor and the nutrient released from the decomposition of litter is crucial to the ecosystems' sustainability (Abelho, 2001). There is limited information on the influence of intercropping on cassava litter fall in Ghana. However, when crops are intercropped, the soil surface is covered by several layers of leaves for longer period of time thereby reducing the impact of rain droplets and wind speed on the surface of the soils limiting the possibility of runoff and erosion by wind (Igbozurike, 1971). The advantage of growing legume such as cowpea, soybean and ground as intercrop with cassava is important due to the role legumes play in the cropping systems. This all important role is in the fixation of nitrogen through their symbiotic relationship with *Rhizobium* species. Nitrogen is also passed into the soil from the top through litter fall which will immensely benefit the associating arable crops.

### Intercrop Productivity

One of the most important reasons to grow two or more crops together is the increase in productivity. Researchers have designed several methods for assessing intercrop performance as compared to pure stand yield (Mead, Willey, & Donald, 1980) but the use of the land equivalent ratio (LER) has become common practice in intercropping studies, because of its relatively simple concept (Kurt, 1984). The land equivalent ratio (LER) may be defined as the relative land area under sole crops that is required to produce the yields achieved by intercropping (Willey, 1979). It is usually stipulated that the "level of management" must be the same for intercropping and sole cropping. In this regard, intercrop and sole crop have to be at their optimum populations as differences in population affects yield responses (Huxley and Maingu 1978).

Kurt, (1984) indicated that an essential concept inherent in the use of LER is such that whatever be their type or level of yield, different crops are placed on a relative and directly comparable basis. He further explained that based on land areas, LER also reflects relative yields (the numerical yield total is numerical to LER) that is, the LER can be taken as a measure of relative yield advantage. It has been documented that intercropping can often improve crop productivity as relative to sole crops (Adam & Mohammed, 2012). In assessing the level of yield advantage in intercrops, land equivalent ratio (LER) is an important tool to measure the levels of intercrop interference going on in the cropping system. It also shows the efficiency of intercropping for using the environmental resources relative to sole cropping system (Chapagain & Riseman, 2014). According to Willey and Rao (1980), LER is calculated as follows:

LER = Σ (YI/YM) where YI represents the yield of each crop in the intercropping system and YM is the yield of each crop in the mono-cropping system.

Theoretically, if the agro-ecological characteristics of each crop in an intercrop are exactly the same, the total LER should be 1.0 and the partial LERs should be 0.5 for each crop (Morales-Rosales and Franco-Mora, 2009). On the other hand, if the total LER is greater than 1, the intercropping favours the yields of crops, indicating yield advantage (Willey, 1980). However, if the total LER is less than 1, the intercropping negatively affects the yields of the crops when the crops were intercropped relative to both crops separately. An LER of 1.5 for instance, indicates that the area planted to mono cropping would need to be 50% greater than the area planted to intercrop for the two crops to produce the same combined yields.

Area by time equivalent ratio (ATER) provides more realistic comparison of yield advantage of intercropping over sole cropping in terms of time taken by the component crops in any given intercropping systems (Aasi, Umer, & Kari, 2004). Component crops differ in their use of growth resources in such a way that when they are grown in combination, they are able to complement each other and so make better overall use of environmental resources than when they are grown in their respective mono-cropping system (Chapagain & Riseman, 2014). Dhandayuthapani & Latha (2015) reported significant variations in land equivalent ratio and area by time equivalent ratio due to cropping systems and planting geometry in an intercropping trial at the Tamil Nadu Agricultural University, India. Study conducted by Ezeibekwa (2009); Thankappan & Abraham, (2015) showed that incorporating groundnut and poultry manure into the cassavas/maize intercrop system, resulted in increased crop productivity evidenced by high LERs.

Intercropping has been reported to have yield advantage over sole cropping. These advantages can occur as a result of complementary use of growth resources such as nutrients, water and light by the component crops (Fukai and Trenbath, 1993). The yield advantage may be in terms of higher yield or higher net income. He further explained that the yield can be quantified in terms of dry matter production, grain or root yields, nutrient uptake, energy or protein production and market value. According to Kurt (1984); Gomez and Gomez (1986) the yield advantage is measured using land equivalent ratio (LER) or Relative yield totals (RYT). LER is defined as the relative land area under sole crop that is required to produce the yield achieved by intercropping at the same management level. While RYT is the sum of the ratios obtained from the relative yields (intercropping yields divided by respective sole crop yields) of the component crops in a mixture using the above calculations, yield advantage have been reported for cassava/maize and cassava/beans mixtures (CIAT 1979). According to Ikeorgu, (1983), cassava/maize intercrop gives higher amount of calories per hectare of land than the pure stands. Also, land equivalent ratio of 1.71 has been reported for cassava/maize intercrop (CATIE, 1977).

Another major advantage of intercropping is yield stability. That means a reliable food production over years that provides a high income for the farmer and enhances diversity of farm products (Rao et al., 2005). Gomez and Gomez (1986) felt that intercropping does not only enhance diversity of farm products but also provides insurance against crop failure. They reported that with diversified crops, intercropping stabilizes yield through the principle of compensation. They explained that when one crop component suffers from pests, diseases, drought etc, the loss of this crop is compensated at least partially by the other component crop(s) since there is now less competition for growth resources, and stated that there would be no compensation if it was only a sole crop.

Spatial arrangements of crops is another form of intercropping when two or more crops are grown in separate rows or alternating rows on the same piece of land. In spatial arrangements, the crops involved compete for growth resources such as light, water, carbon dioxide and nutrients. Differences in the canopies of crops appear to provide more efficient light use by spatial arrangements than by sole cropping.

Competition is one of the factors that can have a significant impact on yield of mixtures compared with pure stands ((Nötzold, Blossey, & Newton, 1998). Higher yields have been reported when competition between two species of the mixtures have lower competition than within the same species (Vandermer, 1990). Competition can also have a significant impact on the growth rate of the different species used in spatial arrangements. A number of advantages have been advanced for the use of spatial arrangements in place of sole cropping. According to Steiner (1982), spatial arrangements bridge the gap between planting and new harvest "the hungry season" where early maturing crops are planted at the beginning of the rainy season. According to Andrews and Kassam (1976), intercropping reduces the damage caused by pest and diseases and ensures greater yield stability by producing from the same field even if some of the crops fail.

Of the numerous advantages attributed to intercropping, perhaps the most important is thetotal yield advantage. Petersen (1994) reported that shading by heavier leaf canopy of an intercropping also reduces soil temperature and moisture loss, which favours multiplication and growth of some soil microorganisms. In spite of the numerous advantages in favour of intercropping, there are some disadvantages associated with it. Addo-Quaye, Darkwa, and Ocloo, (2011)reported that intercropping systems in mechanization is difficult, management requirements are higher and overall cost per unit production may be higher due to reduced efficiency in planting, weeding and harvesting.

For any given species in an intercrop/ mixed cropping systems, relative crowding (k) compare the actual yield per plant in a mixture with an expected yield per plant, which was the yield which could be achieved if the species experienced the same degree of competition in the mixture as in the pure stand (De Wit, 1960). The coefficient is usually designated as ‘K’ and if the product of any given crop in a mixture is greater than, equal to, or less than unity means that the given crop is more, equal, or less competitive than its associated crop ( Rao and Willey, 1980).

Aggressivity was proposed by McGilchrist (1965) as a function which measure the intercrop competition by the relating yield changes of both component crops. Although aggressivity has the merit of trying to relate the yield changes of both crops, it might be more meaningful to calculate the competitive ratio (Willey & Rao, 1980)

The competitive ratio is an important tool to know the degree with which one crop competes with the other crops (Rao & Willey, 1980). The CR simply represents the ratio of individual LERs in intercropping systems. It may be used to estimate the competitive ability of different crops in the mixture, measure the competitive changes in a given situation, identify plant characteristics associated with competitive ability, and determine the competitive balance most likely to give maximum yield.

Soil losses and run-off is limited because the practice of intercropping, more especially multi-storey cropping provides a nearly continuous soil cover thus preventing it from the direct impact of the rains (Kurt, 1984; Gomez and Gomez, 1986). They pointed out that intercropping produces a dense and diversified root system and this reduces leaching of nutrients. Okigbo and Lal (1979) reported that relatively simple intercropping system as maize/cassava can increase the CEC (cation exchange capacity), and pH as well as Mn content in the soil. Furthermore, the integration of trees into cropping systems in the form of alley cropping is another means of maintaining soil fertility. It reduces soil erosion and leaching with the help of the root systems by “pumping up” nutrients to the surface from layers beyond the root systems of annual crops (NRC, 1984). In a farmer-oriented research, IITA Ibadan, Nigeria, has for several years developed a method for planting giant leucaena as an intercrop with corn, yam and rice. In the growing season the trees are kept cut and pruned so that they do not shade the nearby crops. The resulting leaves and twigs are used as nitrogen rich mulch while the larger branches serve as poles or firewood. In the dry season, the tree intercrops are allowed to re-grow and draw nutrients from deep soil levels (IITA, 1979).

Several scientists have compared nutrient uptake in crop mixtures and in pure stands and showed that crops extract more nutrients from the soil when grown in a mixture than when grown in pure stands. For instance, Dalal (1974) compared maize and pigeon pea mixture with pure maize, and observed that the differences in growth duration of the components crops tend to minimize competition. Kassam and Stockinger (1973) shared a similar view when they indicated that intercropping systems were most rewarding in terms of yield of the component crops. In the tropics, the relevance of intercropping legume with other staple food crops is when legumes are capable of fixing nitrogen that will be available to both the legume and component crops (Agboola & Fayemi, 1972).

According to Okigbo, (1978): Kurt (1984), intercrops have better water use efficiency than sole crops. They explained that this is of special importance to farmers in the semi-arid tropics where water is the main limiting factor of production. They reported that one of the reasons for increased water use efficiency of intercrops is the windbreak effect. Okigbo (1978) observed that when low growing crops are inter-planted with tall growing ones, this leads to reduced evapotranspiration.  Again, there is a low population for the residual moisture at the end of the growing season which is another means of using available soil moisture more efficiently by intercropping (Rao & Willey, 1980; Okigbo, 1978).

Intercropping can play a significant role in integrated pest management. There are many cases where pests and especially weeds are suppressed by certain crop combinations like maize/soybean, maize/black gram, maize/velvet bean (Chaud & Sharma, 1977). They reported that in all the crop combinations there were pest (stem borer) reduction in all intercropping involving maize and another crop when compared to sole maize.

### Weed and Intercropping Systems

A weed is plant growing where man does not want it to be (Onwueme & Sinha, 1991). Any kind of plant can be a weed as long as it exists in a location or situation where it is considered undesirable. Weed reduces the yield of crops through competition for environmental resources and causes interference in the farm operations thereby increasing the cost of production (Lawson et al., 2006). Weeding is a major labour requirement for cassava production and weed competition is a major constraint to yield ( Olorunmaiye, 2010). Uncontrolled weed growth can result in almost total yield loss (Patience Mojibade Olorunmaiye & Olorunmaiye, 2009).

It is commonly known that intercropping reduces weed infestation and is one of the integrated weed management strategies with less effect on the environment than the use of chemical herbicides. Light, water, and nutrients utilization may be more completely taken and converted to crop biomass by intercropping; this is as a result of differences in competitive ability for growth factors between intercrop components (Ofori & Stern, 1987; Willey, 1979). Vande(1989) reported that in competition, the various components are not competing for same ecological niches and that intra-specific 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 manage weeds with less use of herbicides (Neumann, Schmidke, & Rauber, 2007).

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 (Lutaladio, Brockman, Landu, Wahua, Hahn, 1988).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 or suppressing the growth of weeds through allelopatic effect (Osundare, 2007).

Cassava (*Manihot esculenta Crantz*) is an annual crop grown widely in the tropics as food and cash crop. Cassava-based cropping systems are prevalent as cassava is one of the major staple foods grown in most sub-Saharan African countries (Mkamilo & Jeremiah, 2005). It is Africa's second most important food staple, after maize, in terms of calories consumed. Intercropping cassava is widely practiced among small-scale farmers in the humid and sub-humid tropics. About 50% of cassava grown in tropical Africa is intercropped with cereals, grain legumes, leafy vegetables, fruits and tree crops (Okigbo & Greenland, 1976). Cassava is commonly grown in association with a short duration crop such as maize or melon in Ghana. Weed infestation is a major constraint in cassava production and the crop is susceptible to weed competition because of its initial slow growth.

Competition from weeds can occur at any period of growth in cassava, but the most damaging effect of weeds have been reported to occur during the early canopy formation and the third month after planting when tuberization commences (Onochie, 1975). Cassava competes well with weeds once canopy is fully formed. However, its ability to compete with weeds depends to some extent on how long after planting the crop stays weed free before canopy completely covers the ground. Traditionally, hand-weeding is the major weed control measure used in cassava production. Intercropping cassava with grain legume is relatively uncommon among farmers in Ghana. In intercropping, the crops are selected to take advantage of different nutrient requirements and differences in plant architecture so as to maximize resource use. Agronomic practices such as plant densities, crop arrangement and relative planting times can increase productivity in cassava-legume intercropping systems (Pypers et al., 2011). Appropriate modification of plant population and crop arrangement is a long recognized weed control strategy (Akobundu, 1984). Hence, the use of low growing crops like soybean, groundnut, and cowpea as weed management strategy in various cropping systems have been extensively studied (Amanullah, Alagesan, Vaiyapuri, Pazhanivelan, & Sathyamoorthi, 2006;Ayoola & Agboola, 2001).In intercrops, intra and/or inter specific competition between crops may occur (Zhang & Li, 2003). This increased competitiveness of intercropping systems makes them potentially useful for adoption into low input farming systems in which options for chemical weed control are reduced or non-existent (Szumigalski & Van Acker, 2005).

Intercropping strategies can reduce weed population density and biomass production (Liebman & Dyck, 1993).

Cassava/groundnut intercropping is practiced in many parts of Central Africa and the two crop species are highly compatible (Lutaladio, Brockman, Landu, Wahua, Hahn, 1988). Groundnut is grown throughout the tropics but it predominates in the seasonally arid areas. It is produced in large quantities in Northern Nigeria; and is gradually being introduced into the farming systems of south western Nigeria for intercropping with crops such as cassava, maize, rice, and vegetables. Groundnut is used as a live mulch since it spreads and covers the ground and suppresses weeds, reducing the impact of raindrops on the soil and thus help in checking both water and wind erosion (Dung et al., 2005). Weed suppression and reduction of weed growth by crop interference has been reported as one major determinant of yield advantage of intercropping, being a viable alternative to reduce the reliance of weed management on herbicide use (Agegnehu et al., 2006;Banik etal., 2006). In intercropping, weed density and biomass is often markedly reduced compared to the sole crop (Henrik, Nielsen, Bjarne, & Steen, 2003)

Most fields are cultivated in mixed or inter cropping, with a variety of crops grown in an often well-defined pattern to maximize use of water, nutrients and light. The obvious reason for this is that farmers need a variety of products. Mixed cropping (including relay-cropping) maintains the soil cover more completely and for a longer period (Rouw, 2001). The soil surface becomes better protected against the violent action of rains and under these shady conditions, few weeds gets a chance to invade. According to Rouw(1991) weeds that grow on a piece of land are adapted to the local conditions and if these conditions change, like another crop is cultivated, or the soil is flooded or tilled, or fertilizers are applied, then the weed population changes as well. Normally, each crop - soil -climate combination has a typical weed species group. One widespread tactic in suppressing weeds is to quickly change the favourable growth conditions for weeds to develop and become a threat to production (De Wet & Harlan, 1975). Crop rotation, flooding, tillage, cover cropping, and fallowing are techniques against the buildup of troublesome weed population.

However, these originally varied populations have evolved into often quasi nonspecific stands under the treatment of advanced techniques, monoculture and high inputs. In modern agriculture, more effort goes into the control of weeds. In tropical regions, both the flora and cultivation practices are far more varied. This offers a variety of possibilities of control and a challenge to do more study on agro-ecology to get a clear view of the often complex situation (Rouw, 2001).

FDA (1994) stressed that until adequate attention is paid to the weed problems confronting different categories of farmers, real progress cannot be made in agricultural development in Nigeria. The total land area a farmer can cultivate is determined to a great extent by how much labour is available to him for weed control. Also in many cases only a farmer and his wife are available to face this great task because their children of school age are generally away from home.

Akobundu (1987) mentioned that weeds determine the farm size and limit of crop production potential of resource poor farmers and indirectly affect the well-being of farm families. According to Lavabre (1991) weeds to some extent affect annual crops but how serious this is depend on the species and circumstances.Nangju (1980) reported on the reductive effect of weed on crop production and indicated that 51% reduction in cowpea yield was due to weed infestation, 65% in cassava, 73% in yam and 80% in maize. Kurt (1984) concluded that yield losses due to weeds are relatively considerable in the tropics but may exceed 50%. He further explained that weed infestation increases with time from clearance onward and after three years the farmers are often forced to abandon a field and clear a new one, because the time needed for weeding is greater than time needed for clearing forest or bush. Moody (1975) established that in Nigeria, at least 50% of a farmer’s working time is spent on weeding and the situation could be similar in the sub-region.

Most crop combinations suppress weed growth by providing an early ground cover especially with high plant population or fast growing component crops (Evans, 1981). In many intercropping systems, only one weeding is required to produce optimum yields instead of three or more in sole crops. Often times, this weeding is combined planting another intercrop thus further reducing the time required solely for weeding (Kurt, 1984). Researchers in CIAT (1979) reported that in intercropping systems involving cassava-beans, weed growth was minimized considerably in Central America. They explained that with this result, frequent weeding of pure cassava was no more efficient in weed control than intercropping cassava with beans. Belel, Halim, Rafii, & Saud (2014)) explained that the success of an intercropping depends on soil fertility and climate as well. They further mentioned that the suppression of weeds is often higher with low soil fertility than with high soil fertility and the same applies to low and high rainfall areas.

## Summary of Literature Reviewed and Research Gaps

The literature reviewed has established that soil fertility is a major determinant of agricultural productivity. A number of different cropping systems are practiced in Sub-Saharan Africa ranging from shifting cultivation through fallow systems to continuous cropping. With the increase in population pressure there is a tendency towards continuous cropping and a serious danger of a steady depletion of soil fertility. Effective nutrient management is therefore, a critical part of crop production not only to improve farmer's income, but also to maintain soil quality and reduce the likelihood of damage to the environment.

The use of inorganic fertilizers in crop production is declining since they are beyond the means of most resource poor farmers. Therefore, soil fertility decline is a fundamental cause for slow growth in crop production in SSA. Small-holder farmers are the main growers of cassava in Ghana and mostly grow cassava on marginal areas. Even though, cassava shows response to fertilizer application, poorly resourced farmers rarely use fertilizer in cassava crop production. Limited use of inorganic fertilizers has led to declining soil fertility in cassava-based farming system in SSA. In this case, integrating fertilizer inputs in cassava-legume intercropping alternatives may be a sound management option for those small-holder farmers to sustain soil fertility and cassava production. In addition, farmers mostly grow low yielding local varieties of cassava. Since ISFM strategies appropriate to cassava based production system in the humid tropics are not yet fully developed, there is need to improve the agronomic efficiency of nutrient inputs in cassava-based farming systems of Ghana to increase crop yields and economic returns.

Cassava-legume intercropping systems have been a common practice among small-scale farmers with the aim of making more efficient use of the available growth resources and for nutrient requirements based on the complementary utilization of growth resources as well. Since the spatial arrangement influences the utilization efficiency of environmental factors and the degree of competition between component crops, it is a main aspect in the productivity of an intercropping system. The effect of different legumes on the yields of component crops in the cassava-legume intercrop is not fully developed. Information on optimum planting density of component crop for maximum root yields of cassava is also not well documented in cassava-grain legume intercropping in Ghana. Moreover, the relative planting time of cassava has not been widely studied in the cassava-cowpea, cassava-groundnut, and cassava-soybean intercrops in Ghana.

# CHAPTER THREE

# EFFECTS OF FERTILIZER AND CASSAVA-LEGUME CROPPING SYSTEMS ON ROOT AND GRAIN YIELDS IN TWO AGRO-ECOLOGICAL ZONES OF GHANA

## Introduction

Cassava (*Manihot esculenta Crantz*) is an important staple food crop in Ghana with per capita consumption of about 153 kg/year (MoFA, 2012a). Cassava is cultivated as a monocrop or an intercrop with other food crops either as the main or subsidiary crop and it covers about 21.68% of the total area of land grown to food crops in Ghana (MoFA, 2012b) and the area cropped to cassava increased from an average of 577,100 ha in 1995-1997 to 889,364 ha in 2011 (MoFA, 2009- 2012). In the forest/savanna transitional agro-ecological zone of Ghana where the bulk of cassava is produced, cassava has multiple uses. Despite being a major staple food crop, cassava serves as a source of income for most rural dwellers where it is processed into either gari or cassava chips and exported to neighbouring countries. In the forest/savanna transitional zone in Ghana in general and Wenchi in particular, cassava cropping is also used as a strategy to regenerate degraded soils (Adjei-Nsiah et al., 2004, Adjei-Nsiah et al., 2012).

Several grain legumes, including cowpea, groundnut, and soybean are selected as companion crops in many intercropping practices in the tropics due to their short duration and suitability in a cassava based intercrop (Polthanee, et al. 2001). Although introducing leguminous crops in intercropping systems is a unique strategy for soil N improvement, Sanchez et al (1997) argued that organic sources cannot replenish soil fertility decline by themselves alone as they are gradually not available in sufficient quantities in most farms to fulfill the nutrient requirement of crops that will increase yield. Application of NPK fertilizer in cassava-legume based intercrop could be the best agronomic practice to improve soil fertility and increase crop yield.Ayoola & Adeniyan (2006) reported an increase in cassava root yield by 73 to 95 % with the combined application of organic input and inorganic fertilizer in Nigeria.

In Ghana, Cassava is found in a variety of crop production systems and performs well under various levels of management. Incorporating grain legumes into cassava based cropping system may be a desirable strategy to enchase protein intake and nutritional security for resource poor farmers whose staple is purely cassava. Stephenson et al., (2010) reported a high risk of insufficient protein intake for children between the ages of 2-5 consuming cassava as main staple in Nigeria and Kenya. Cassava is a stable for more than 80 million people living in developing countries (Burns et al., 2010) and has the potential to replace expensive imported raw materials such as starch and wheat flour for various African Industries. Ogola and Magongwa, (2013) asserted that incorporating grain legumes into cassava based cropping system could augment the overall productivity of the system.The objective of the study was to evaluate the effects of fertilizer and cassava-legume based intercropping systems on growth and yield components of cassava and component crops.

## Materials and Methods

### Study Areas

The study was carried out concurrently in the forest transitional savannah zone of Wenchi ($7^0$ 44/ N, $2^0$ 6/ W), in the Brong Ahafo region, and the rain forest zone of Kwadaso, in the Ashanti region (6°40′59″ N, 1°37′00″ W). The trials were established in April 2014 through December 2015. The study sites are characterized by a bimodal rainfall pattern. The major growing season is from April to July while the minor growing season is from September followed by a dry season from December to March.

## Experimental Design and Layout

A factorial experiment comprising of two factors, fertilizer (3 levels) and cropping system (4 types), arranged in a Randomized Complete Block Design (RCBD) with 3 replications was used. The three fertilizer rates (0 N – 0 $P_2O_5$ – 0 $K_2O$ kg/ha(control), 15 N – 15 $P_2O$ – 15 $K_2O$ kg/ha, and 30 N – 30 P2O5 – K $_2$O kg/ha) were applied to the cassava crop in the following cropping systems: Pure stand cassava, Cassava + cowpea, Cassava + Soybean, and Cassava + Groundnut. A plot size measuring 5.0 m x 10.0 m was adopted for each treatment. There were five rows of cassava in each plot. The first row was separated by 150 cm from the second, with 100 centimeters between the second and third rows. Another 150 centimeters space was maintained between the third and fourth rows and subsequent rows (fourth and fifth) were spaced at 100 centimeters. Consistently 100 cm intra-row spacing was maintained for each row in a plot. Legume crops were spaced at 50cm between rows with varying intra-row space of 20 cm, 15 cm, and 30 cm for cowpea, soybean, and groundnut respectively.Details of the treatments are shown in Table 1. Fertilizer was applied in a round circle from about 100 $cm^2$ from the cassava crop.

Prior to trial establishment, cassava was grown two years in succession at the Wenchi Site while the site at Kwadaso was under fallow for nearly one year.

One cassava variety namely *Essam bankye* and one variety each of the three component legume crops was used in this study. The varieties of the grain legume used in the study included *Asomdwee* (cowpea), *Nangbaa* (soybean), and *Yenyawoso* (groundnut).

In both locations, land preparations were done manually with machetes and hoes. Debris were packed and removed from the site and the field was marked out for planting. Planting was done manually using a hand held hoe.

Table 1: *Description of Treatment Combinations*

| Cropping system | Fertilizer rates ( N-P2O5-K2O kg/ha) |
|---|---|
| Pure stand | 0 |
| | 15 |
| | 30 |
| Cassava + Cowpea | 0 |
| | 15 |
| | 30 |
| Cassava + Soybean | 0 |
| | 15 |
| | 30 |
| Cassava + Groundnut | 0 |
| | 15 |
| | 30 |

### Parameter Measured

### Agronomic Performance of Cassava in the Intercrops

Important characteristics of the cassava growth habits including height, girth, and leaf area were measured at thirty days interval. Ten plants were tagged for subsequent measurement of selected parameters of Cassava.Meter rule was used to measure the height of cassava plant from the base to the apex. A potable caliper was used to measure the girth at the base of stem about 10 cm above the ground. Leafarea was estimated non-destructively by counting the number of leaves per plant and subsequently estimated for an area of 10 square meters(Ekanayake et al., 1996).From that, the leaf area index was obtained as follow:

Leaf area index (LAI) = L/P where L is the leaf area and P is the ground area.

Exactly six months after planting, litter trap was set in each plot measuring 100 by 100 square centimeters and raised slightly above ground to trap fallen leaf litter. The litter wascollected every four weeks, oven dried at 70°C for 2 days for dry matter determination.

Total biomass for cassava was determined at harvest. An area of 10 $m^2$ was harvest at 12 months after planting and separated into stem and leaves components. The roots were separated into marketable roots, non-marketable roots, and rotten roots as the case was for each plot.

### Agronomic Performance of Component Crops in the Intercrop

In this study, the three grain legume (cowpea, soybean, and groundnut) were consider as component crops. Leaf area was determined using similar procedures as described by Ekanayake et al.,( 1996). Cowpea and soybean were harvested at 90 days while groundnut was harvested at 120 days after planting in an area of 4 $m^2$. Total biomass for each of the three legume crops was determined at harvest.

### Weed biomass

Weed samples were collected with a 50 cm × 50 cm quadrate at two spots in each plot at 4 and 8 weeks after planting for weed dry weight determination. The weeds were cut above soil level and oven-dried at 80 Cand then weighed.

### Data analysis:

Data on all parameters were subjected to analyses of variance (ANOVA) using Genstat statistical package. Least Significant Difference (LSD) was used as mean separates

## Results and Discussion

### Mean Root Number

Mean number of roots per plant obtained in this study are presented in Table 2. Among all cropping systems at Kwadaso, mean number of roots per plant ranged from 7.4 under pure stand to 8.4 under for cassava-cowpea and cassava-groundnut with fertilizer treatments given mean range of 7.4 to 8.5 for control treatment ( 0 N-$P_2O_5$-$K_2O$ kg/ha) and 15N-$P_2O_5$-$K_2O$ kg/ha respectively. However, mean root number per plat at Kwadaso was neither influenced by treatments interactions nor their single effects. Pure stand and cassava-cowpea gave the lowest mean number of root per plant of 6.9 per plant while cassava-soybean gave the highest of 7.5 roots per plant at Wenchi. Similarly, there was no significant effect on mean root number per plant due cropping systems. Unlike Kwadaso, significant differences among fertilizer treatments on mean number of roots per plant were observed at Wenchi. Mean number of roots per plant increased from 6.3 to 8.0 as the level of fertilizer increased with 30 N-$P_2O_5$-$K_2O$ kg/ha recording the highest mean number of roots per plant but was not statistically different for the mean obtained at 15N-$P_2O_5$-$K_2O$ kg/ha. Control treatment recorded the lowest mean number of roots per plant but did not vary significantly from the result obtained when 15N-$P_2O_5$-$K_2O$ kg/ha was applied.Generally, the study showed relatively higher number of roots per plant at Kwadaso as compared to Wenchi.

The addition of fertilizer and cassava inter-planted with legumes did not influence mean number of roots per plant at Kwadaso probably due tothe moderate initial soil nutrient level that may have favoured the nutritional requirements for the cassava crop. According toHowever (2002), average soil value of1.5cmol/kg for exchangeable potassium and 10ppm for available phosphorus are critical levels for cassava nutritional requirements. These findings are also similar to Nyi(2014) who reported high number of cassava roots per plants in regions with low soil nutrient levels in DR Congo relative to regions with high soil nutrient levels where fertilizer did show significant effect on number and yield of cassava.In the case of Wenchi, nutrient supplied through NPK fertilizer may have been effective in supporting tuber initiation since initial soil nutrient level was below critical nutritional requirements for cassava especially so for exchangeable K. Additionally, this could be as a result of better synchronization of nutrient release and uptake by plants (Kapkiyai, et al, 1998).

Table 2: *Number of Cassava Roots per Plant as Influenced by Different Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 7.1 | 6.6 | 7.4 | 7.1 | 7.7 | 7.1 | 7.4 | 6.9 |
| Cassava-cowpea | 6.9 | 5.2 | 9.5 | 7.5 | 8.8 | 8.2 | 8.4 | 6.9 |
| Cassava-soybean | 7.7 | 6.9 | 8.5 | 7.1 | 8.6 | 8.6 | 8.3 | 7.5 |
| Cassava-groundnut | 7.7 | 6.7 | 8.8 | 7.3 | 8.7 | 7.9 | 8.4 | 7.3 |
| Mean for Fert. | 7.4 | 6.3 | 8.5 | 7.2 | 8.4 | 8.0 | | |

| | P-VALUE | | SED | | LSD | |
|---|---|---|---|---|---|---|
| Fertilizer | NS | 0.02 | 0.6 | 0.6 | | 1.1 |
| Cropping systems | NS | NS | 0.7 | 0.7 | | |
| Fert x CPS | NS | NS | 1.3 | 1.2 | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Such effect might contribute to increase fertilizer use efficiency and provide more balanced supply of nutrient. The findings are in close conformity with Adjei-Nsiah, (2010)who reported significant increase in the number of cassava roots per plant at 30-60 N-$P_2O_5$-$K_2O$ kg/ha. Assessment of the initial soil conditions at the both study sites showed that the soil condition at Kwadaso was ideal to support cassava production. This could probably be the major factor responsible the differences in the number of roots per plant as relatively higher root numbers per plant was recorded at Kwadaso as compared to Wenchi.

**Mean Root Weight**

Mean root weight (kg/root) ranged from 0.7 to 0.8among fertilizer treatments at Kwadaso (Table 3). The control treatment (0 N-$P_2O_5$-$K_2O$ kg/ha) and 30 N-$P_2O_5$-$K_2O$ kg/ha recorded similar root weight which was, however, higher than the mean root weight reported in plots treated with 15 N-$P_2O_5$-$K_2O$ kg/ha. Among cropping systems at Kwadaso, cassava-groundnut recorded the highest root weight (0.9 kg/root) relative to cassava-soybean and cassava-cowpea. The lowest mean root weight (0.7 kg/root) was reported under pure stand cropping system. At Wenchi (Table 3), mean root weight ranged from 0.4 to 0.5 kg/root under fertilizer treatments. Mean root weight did not vary with increasing fertilizer treatment from 15-30 N-$P_2O_5$-$K_2O$ kg/ha while control plots gave the lowest mean root weight. Similar observation was made among the cropping systems with pure stand (control) given the lowest of 0.4 kg/root. The study showed higher mean root weight at Kwadaso relative to which implies that the root yield at Kwadaso was higher than what was obtained at Wenchi.

Table 3: *Mean Root Weight (kg) of Cassava as Influenced byDifferent Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 0.7 | 0.3 | 0.7 | 0.5 | 0.7 | 0.5 | 0.7 | 0.4 |
| Cassava-cowpea | 0.8 | 0.5 | 0.8 | 0.5 | 0.7 | 0.5 | 0.8 | 0.5 |
| Cassava-soybean | 0.8 | 0.4 | 0.7 | 0.7 | 0.7 | 0.5 | 0.8 | 0.5 |
| Cassava-groundnut | 0.8 | 0.6 | 0.8 | 0.5 | 1.0 | 0.4 | 0.9 | 0.5 |
| Mean Fert. | 0.8 | 0.4 | 0.7 | 0.5 | 0.8 | 0.5 | | |
| | P-VALUE | | SED | | | | | |
| Fertilizer | NS | NS | 0.1 | 0.1 | | | | |
| Cropping systems | NS | NS | 0.1 | 0.1 | | | | |
| Fert x CPS | NS | NS | 0.1 | 0.1 | | | | |

NS: Non significant, RT: Root, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

The relatively better soil nutrient level at Kwadaso might have stimulated net photosynthetic activity and increases the translocation of photosynthates from the leaves to the storage roots (However, 2001). However, the study did not showed significant difference on mean root weight due to fertilizer application or cropping systems. The result is in line with previous study of Parkes, Allotey, and Akuffo (2012)who investigated fertilizer and cassava intercropped with four grain legumes and found that there was no significant effect of mean root weight due to fertilizer or cropping systems when soil nutrient requirements was relatively satisfactory in the second year of cropping.

### Root Yield

The result of this study as displayed in Table 4 did not show interaction effect of fertilizer and cropping systems on root yield across the two locations (Kwadaso and Wenchi). At Kwadaso, root yield was significantly ($P<0.02$) influenced by cropping systems. Cassava and legume combinations (the intercrops) recorded significantly higher root yield relative to the control (pure stand). This might be due to the ability of the legume to provide adequate groundcover to retain soil moisture andimprove thesoil nitrogen level. Moreover, intercropping cassava with legume could also add organic matter input to the soil through the addition of legume biomass which improves physical, chemical, and biological properties of the soil and attendant increase crop yield (Gerh, Lot, and Aarh, 2006). The root yield observed under cassava-groundnut (70.2 t/ha) was significantly higher than the pure stand but was not different from other cropping systems. Cassava-groundnut and cassava-cowpea (65.1 t/ha) were significantly higher than the pure stand. Conversely, pure stand and cassava-soybean did not differ significantly. The root yield observed under cassava-soybean and cassava-cowpea was not significantly different from each other. Pure stand recorded significantly lowest root yield in this study. The higher tuberous root yield observed under cassava-groundnut and cassava-cowpea intercrops could due to the fact that groundnut and cowpea are short duration crops and matured just after the maximum canopy development of cassava and harvested earlier before an increase rate of tuber bulking process in the cassava crop. Additionally, cassava might have taken advantage of inter-specific competition for growth resources (space, water, and nutrient) between the two crops for cassava was planted two weeks prior to introducing the legumes in their respective intercrops. Nyi, (2014) also found that cassava yield can increased considerably if cassava is planted early than the associated crop in an intercrop, creating strong inter-specific competition for growth resources in favour of the cassava crop at the time when the associated crop is still a weak competitor. The results suggest that cassava can be planted two weeks after groundnut and cowpea without affecting the tuberous root yield in the cassava-groundnut and cassava-cowpea intercrops.

At Wenchi, mean root yield obtained under fertilizer treatments ranged from 28.9 to 34.6 t/ha. The lowest mean root yield was observed under control treatment with 15 N-$P_2O_5$-$K_2O$ kg/ha giving the highest root yield. Similar observation was reported among cropping where pure stand (control)gave the lowest root yield of 30.7 t/ha. Cassava-soybean intercropping systems recorded the highest yield of 38.6 t/ha.

Table 4: *Effect of Fertilizer and Cropping Systems on Root Yield (t/ha) of Cassava*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 51.3 | 24.8 | 45.1 | 32.2 | 56.7 | 34.9 | 51.0 | 30.7 |
| Cassava-cowpea | 57.7 | 26.7 | 74.2 | 32.6 | 63.6 | 37.1 | 65.1 | 32.1 |
| Cassava-soybean | 62.3 | 28.5 | 61.8 | 46.4 | 62.8 | 41.0 | 62.3 | 38.6 |
| Cassava-groundnut | 60.5 | 35.6 | 68.5 | 35.0 | 81.5 | 32.4 | 70.2 | 34.3 |
| Mean for Fert. | 58.0 | 28.9 | 62.4 | 36.5 | 66.1 | 36.4 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 5.1 | 3.4 | | | | |
| Cropping systems | 0.03 | NS | 5.9 | 3.9 | 12.2 | | | |
| Fert. x CPS | NS | NS | 10.3 | 6.8 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

However, the study did not indicate significant difference on root yield due to fertilizer or cropping systems. This might be associated to the low soil nutrient level as nutrients supplied through fertilizer and legumes inter-planted with cassava might not have been adequate to rescue the situation of low soil nutrient during the first growing season. Several authors (Dung et al. 2005; Osundare, 2007; Mebah et al. 2011) have shown that in the first growing season, crop grown in association with legumes in areas with low soil nutrient level, in most cases, the intercrops would make the most positive effect on yield and yield components in subsequent growing season.

### Plant Height

The result of the effect of fertilizer and cropping systems on the plant height of cassava observed at Kwadaso and Wenchi are presented in Table 5. Plant height at Kwadaso varied from 152.3cm to 176.6cm among fertilizer treatments. Higher plant heights were attained at an increasing fertilizer levels. On the other hand, mean plant height obtained among cropping systems ranged from 163.0cm to 166.1cm. Mean plant did not vary widely among cropping systems, even though, lower mean values were obtained under cassava-cowpea intercrop with cassava-soybean intercrop given the highest plant height. The results obtained for mean plant height at Wenchi were relatively lower than what was reported at Kwadaso with mean value ranging from 115.8cm to 118.1cm among fertilizer treatments and 114.4118.6 among cropping systems. However, this study did not show significant effect on cassava plant height as a result of fertilizer or cropping system. Plant height is a major determinant of species ability to compete for light.

Table 5: *Cassava Plant Height (cm) as Influenced by Different Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 153.7 | 115.6 | 159.4 | 117.9 | 177.4 | 119.9 | 163.5 | 117.8 |
| Cassava-cowpea | 150.6 | 117.8 | 167.8 | 110.4 | 170.7 | 114.9 | 163.0 | 114.4 |
| Cassava-soybean | 144.3 | 114.7 | 171.2 | 124.1 | 182.7 | 117.2 | 166.1 | 118.6 |
| Cassava-groundnut | 160.6 | 115.6 | 161 | 120.1 | 175.4 | 111.1 | 165.6 | 115.6 |
| Mean for Fert. | 152.3 | 115.9 | 164.9 | 118.1 | 176.6 | 115.8 | | |

| | P-VALUE | | SED | | LSD | |
|---|---|---|---|---|---|---|
| Fertilizer | NS | NS | 9.9 | 2.9 | | |
| Cropping systems | NS | NS | 11.5 | 3.3 | | |
| Fert x CPS | NS | NS | 20.0 | 5.8 | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Probably there might have been better soil moisture conditions at Kwadaso which may have influenced the increment in plant height relative to Wenchi where the rains delayed from the onset of the experiment. According to Amanullah, Khattak, and Khalil(2009), species in an intercrop show significant variation in their ability to tolerate moisture stress with decline in field performance for plant height.

**Stem Girth**

Stem girth was not significantly influenced by interaction effects of fertilizer and cropping systems at the both study sites (Table 6). At Kwadaso, mean stem girth varied from 84.9 mm to86.2mm among fertilizer treatment and 85.3 mm to 86.1 mm among cropping systems. Result of this study did not show significant effect of fertilizer and cropping systems on stem girth at Kwadaso. On the other hand, application of fertilizer significantly increased stem girth at the Wenchi study site.The highest level of fertilizer treatment (30N-$P_2O_5$-$K_2O$) recorded the largest mean stem girthof 93.0 mm but not differ statistically from the result obtained when 15 N-$P_2O_5$-$K_2O$ kg/ha was applied. In similar experiment, Ayoola (2011) reported 37-97% increase in cassava stem diameter with the application of inorganic fertilizer in Nigeria. This could be attributed to the increasing nutrient availability to cassava by application of fertilizer especially in areas with low soil fertility status prior to crop establishment. This study showed that the control plot (0 N-$P_2O_5$-$K_2O$ kg/ha) recorded significantly lowest stem girth (90.4 mm). Ado-ekiti and Olusegun (2015) have indicated that stem girth is strongly influenced by soil, water, nutrient, and plant competition due to plant density whose optimization is necessary to maximize the genetic potential of a given crop.

Table 6: *Cassava Stem Girth (mm) as Influenced by Different Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 84.1 | 90.9 | 86.3 | 92.1 | 85.5 | 93.3 | 85.3 | 92.1 |
| Cassava-cowpea | 84.2 | 90.4 | 87.1 | 92.8 | 87.2 | 92.9 | 86.1 | 92.0 |
| Cassava-soybean | 85.7 | 90.1 | 85.7 | 92.3 | 86.8 | 93.3 | 86.1 | 91.9 |
| Cassava-groundnut | 85.8 | 90.1 | 84.8 | 92.6 | 85.4 | 92.5 | 85.3 | 91.7 |
| Mean for Fert. | 84.9 | 90.4 | 86.0 | 92.4 | 86.2 | 93.0 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | <0.01 | 0.6 | 0.8 | | 1.7 | | |
| Cropping systems | NS | NS | 0.7 | 0.9 | | | | |
| Fert x CPS | NS | NS | 1.2 | 1.6 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

The mean stem girth reported at Wenchi appeared to be larger than the values recorded at Kwadaso. Perhaps, the smothering effect of the legumes as a result of their luxuriant vegetative growth at Kwadaso could account for the differences in stem girth. Such effect could favour taller plants than bigger stems especially when the smothering effects are severe prior to full canopy (Amanullah et al., 2009).

### Total Biomass (Cassava)

Table 7 contained the results obtained for total biomass yield at Kwadaso and Wenchi. Mean biomass yield ranged from 93.5 t/ha to 113.1 t/ha for fertilizer treatments and 91.5 t/ha to 119.1 t/ha for cropping systems at Kwadaso. However, the main and interaction effects of treatments in this study did not significantly affect total cassava biomass yield at Kwadaso.Similarly, fertilizer application and cropping systems did not significantly influence the result obtained for the total biomass yield at Wenchi.Mean recorded under fertilizer treatments varied from 47.3-59.6 t/h. Among the cropping systems, cassava-soybean gave the highest mean. The nutrients supplied through fertilizer may not have been readily available to the cassava crop. Such effect could contribute to decreasein photosynthetic area and thereby reduce biomass production (Laghari et al, 2010).One would expect a huge difference in total biomass between the two sites (Kwadaso and Wenchi) as the yield and yield components of cassava reported for Kwadaso were almost double the values observed at the Wenchi.

Table7: *Effect of Fertilizer and Cropping Systems on the Total Biomass Yield (t/ha) of Cassava*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 87.5 | 45.3 | 91.1 | 53.1 | 96.0 | 54.5 | 91.5 | 50.9 |
| Cassava-cowpea | 93.7 | 43.8 | 129.7 | 53.4 | 116.5 | 56.9 | 113.3 | 51.4 |
| Cassava-soybean | 104.8 | 44.7 | 101.3 | 73.7 | 105.8 | 60.3 | 104.0 | 59.6 |
| Cassava-groundnut | 104.2 | 55.5 | 119.2 | 58.0 | 134.0 | 52.9 | 119.1 | 55.5 |
| Mean for Fert. | 97.5 | 47.3 | 110.3 | 59.6 | 113.1 | 56.1 | | |

| | P-VALUE | | SED | |
|---|---|---|---|---|
| Fertilizer | NS | NS | 9.6 | 4.9 |
| Cropping systems | NS | NS | 11.1 | 5.7 |
| Fert x CPS | NS | NS | 19.2 | 9.9 |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Thus suggesting the ability with which the cassava crop partitioned resources between vegetative and reproductive structures in a relatively good soil conditions at Kwadaso. The values obtained for the total biomass of cassava at Kwadaso are not widely different from the figures reported by Esiape (2015) in a study to assess the influence of intercropping on growth and yield of cassava under similar agro-ecological at the Crop Research Institute, Fumesua, Kumasi, Ghana.

### Marketable Root

There was no significant effect observed on mean marketable root number per plant due to interaction effects between fertilizer levels and cropping systems in this study (Table 8).However, mean marketable roots per plant were significantly affected by cropping systems with cassava-ground and cassava-cowpea given the highest of 6.8 and 6.2 roots per plant. There was no significant difference among cassava-groundnut, cassava-cowpea, and cassava-soybean intercrops. Pure stand recorded significantly lower mean marketable root number per plant (4.8 root/plant) than cassava-groundnut and cassava-cowpea but did not vary significantly from the mean obtained when cassava was intercropped with soybean. It could be assumed that the different legume intercrops might have contributed to maintaining a good soil moisture level which is highly required for photosynthesis and tuber bulking. Moreover, due to the fact that the intercropped legume matured before competition developed between the two crop species, cassava had time to recover from the competitive effects of the legume (Fukai et al., 1990).

Table 8: *Number of Marketable Roots per Plantas Influenced by Different Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 4.9 | 2.1 | 4.2 | 2.7 | 5.4 | 2.9 | 4.8 | 2.6 |
| Cassava-cowpea | 5.5 | 2.5 | 7.1 | 3.0 | 6.1 | 3.4 | 6.2 | 2.9 |
| Cassava-soybean | 6.0 | 2.6 | 5.8 | 4.3 | 6.0 | 3.8 | 5.9 | 3.6 |
| Cassava-groundnut | 5.9 | 3.2 | 6.6 | 3.2 | 7.9 | 3.0 | 6.9 | 3.1 |
| Mean for Fert. | 5.6 | 2.6 | 5.9 | 3.3 | 6.3 | 3.3 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 0.5 | 0.3 | | | | |
| Cropping systems | <0.04 | NS | 0.6 | 0.4 | 1.3 | | | |
| Fert x CPS | NS | NS | 1.1 | 0.6 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Thus, cassava tuber initiation and bucking were not severely subjected to the intercrop competition, having harvested the legume earlier before the tuberization process commenced in cassava. Several authors including Polthanee et al (2001) in a cassava-legume intercrop, Dung (2002) in a cassava-groundnut intercrop, Osundare (2007) in a cassava-legume intercrop, and Mbah et al (2011) in a cassava okra intercrop reported a positive effect of intercropping on cassava marketable root yield as compared to pure stand.

Conversely, neither fertilizer nor cropping systems seem to have contributed significantly to the mean marketable root number per plant recorded at Wenchi (Table 8). Mean number of marketable roots per plant observed among fertilizer treatments and cropping systems ranged from 2.6 to 3.3 roots/plant and 2.6 to 3.6 roots per plant. This might be associated to the differences in soil fertility status within the two study sites(Nyi, 2014) as competition for growth resources intensified between cassava and associated crop in a nutrient deficient soil especially when such occur during tuber bulking process, the resultant effects could reduce the yield and yield quality of cassava (However, 2002). This could have probably accounted for the huge difference in the mean marketable roots per plant between the two sites.

**Non-marketable**

The number of non-marketable root per plant varied from 2.1 to 2.4 roots per plant among fertilizer treatments and ranged from 1.9 to 2.6 roots per plant under the cropping systems at Kwadaso. At Wenchi, mean number of non-marketable roots ranged from 2.2 to 2.7 roots/ per plant among fertilizer treatments and cropping systems.

Table 9: *Number of Non-marketable Roots per Plant asInfluenced by Different Rates of Fertilizer and Cropping Systems*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 2.6 | 2.1 | 2.8 | 2.1 | 2.3 | 2.6 | 2.6 | 2.2 |
| Cassava-cowpea | 2.2 | 1.9 | 2.2 | 2.9 | 2.3 | 3.3 | 2.3 | 2.7 |
| Cassava-soybean | 2.1 | 2.4 | 2.4 | 2.6 | 2.4 | 2.9 | 2.3 | 2.6 |
| Cassava-groundnut | 2.1 | 2.3 | 2.0 | 2.3 | 1.6 | 2.7 | 1.9 | 2.4 |
| Mean for Fert. | 2.2 | 2.2 | 2.4 | 2.5 | 2.1 | 2.7 | | |

| | P-VALUE | | SED | | LSD | |
|---|---|---|---|---|---|---|
| Fertilizer | NS | NS | 0.3 | 0.3 | | |
| Cropping systems | NS | NS | 0.3 | 0.3 | | |
| Fert. x CPS | NS | NS | 0.6 | 0.6 | | |

NS: Non significant, Fert.: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Table 10: *Number ofRotten RootsperPlant as Influenced by Different Rates of FertilizerandCropping System*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 1.0 | 0.8 | 1.1 | 0.7 | 0.9 | 0.8 | 1.0 | 0.8 |
| Cassava-cowpea | 0.8 | 0.7 | 0.7 | 0.8 | 0.8 | 0.7 | 0.8 | 0.7 |
| Cassava-soybean | 0.9 | 0.7 | 1.0 | 0.7 | 0.9 | 0.8 | 0.9 | 0.7 |
| Cassava-groundnut | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.7 | 0.7 |
| Mean for Fert. | 0.9 | 0.7 | 0.9 | 0.7 | 0.8 | 0.8 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 0.1 | 0.04 | | | | |
| Cropping systems | NS | NS | 0.1 | 0.04 | | | | |
| Fert x CPS | NS | NS | 0.2 | 0.10 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

The lowest mean value of nonmarketable roots per plant was observed under pure stand while cassava-cowpea and cassava-soybean gave higher values relative to cassava-groundnut. However, the results of this study did not show single or interaction effects between fertilizer and cropping systems on the mean number of nonmarketable roots per plant.

Tuberous roots that were classified as nonmarketable roots were either too small in size or were damaged by pests or diseases. It is noteworthy to say that even though treatments did not influence nonmarketable roots per plant, these conditions were least observed in the intercrops at Kwadaso. Nyi (2014) reported similar result. The author did not find significant effect between pure stand cassava and cassava-legume intercrops on nonmarketable root yield

### Rotten Root

Mean number of rotten roots per plant varied from 0.8 to 0.9 among fertilizer treatments and ranged from 0.7 to 0.9 roots/ plant under cropping systems at Kwadaso. At Wenchi, mean rotten root per plant ranged from 0.7 to 0.8 for fertilizer treatments and cropping systems. Neither fertilizer application nor cropping systems showed significant influence on the number of rotten roots per plant in this study. The low incident of rotten roots in this study could be due to the fact the soils in the study area were not water logged soils or poorly aerated as such condition could retard root development and subsequently lead to root rot (Agbaje & Akinlosotu 2004).

### Harvest Index

The harvestindex indicates the translocation of dry matter produced into sink or harvestable Portion (Alves, 1998). At Kwadaso (Table 11), the dry matter removed from the field as harvest index or storage roots ranged from

0.57 to 0.59 among fertilizer treatments and varied from 0.56 to 0.60 under all cropping systems.However, the result obtained showed no significant effect on harvest index either as a result of interactions or single effects of fertilizer and cropping systems. In similar experiment conducted by Esiape (2015) in the rainforest agro-ecological zone, the percent dry matter obtained from the field as harvest index was about the same values obtained at Kwadaso. Similarly, the author did not observe significant effect on harvest index due to cropping systems or fertilizer application.

Result obtained for mean harvest index at Wenchi ranged from 0.34 to 0.38 under fertilizer treatments and 0.34 to 0.40 among cropping systems. Control plots under fertilizer treatments gave the highest mean harvest index. Similar observation was made among cropping systems where pure stand (control) gave the mean value of 0.40. However, the study did not show significant effects on harvest index as a result of fertilizer application and cropping systems. Sarfo (2015)obtained similar resultin an experiment to assess the effect of organic and inorganic fertilizers on growth, yield and root quality of cassava. The values were high at Kwadaso relative to Wenchi indicating a good balance of assimilates directed to the storage root.A cassava growth model, described by Cock et al. (1979) assumed that the storage roots received only the assimilate that remained after meeting all the growth needs of the plant canopy.

Table 11**:** *Effects ofFertilizer and Cropping Systems onHarvest Index of Cassava*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 0.57 | 0.46 | 0.52 | 0.39 | 0.59 | 0.36 | 0.56 | 0.40 |
| Cassava-cowpea | 0.63 | 0.39 | 0.58 | 0.37 | 0.56 | 0.33 | 0.58 | 0.36 |
| Cassava-soybean | 0.60 | 0.35 | 0.61 | 0.36 | 0.59 | 0.30 | 0.60 | 0.34 |
| Cassava-groundnut | 0.58 | 0.34 | 0.59 | 0.38 | 0.61 | 0.37 | 0.59 | 0.36 |
| Mean for Fert. | 0.59 | 0.38 | 0.57 | 0.37 | 0.59 | 0.34 | | |
| | P-VALUE | | SED | | | | | |
| Fertilizer | NS | NS | 0.02 | 0.02 | | | | |
| Cropping systems | NS | NS | 0.03 | 0.02 | | | | |
| Fert x CPS | NS | NS | 0.05 | 0.04 | | | | |

NS: Non significant, Fert.: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

## Leaf Litter

In addition to the biomass, cassava litter was estimated at full canopy (six months after planting) through to harvest (12 months after planting). The mean are presented in Table 12.Mean values varied from 14.3-16.1 g/m$^{-2}$ among fertilizer treatment at Kwadaso. Plots receiving 15 N-$P_2O_5$-$K_2O$ kg/ha recorded relatively higher value as compared to rest of the fertilizer levels. Among the cropping systems, mean values ranged from 14.4-15.5 g/m$^{-2}$. The amount of litter recorded at Kwadaso was unaffected by fertilizer application, cropping systems and interactions between fertilizers and cropping. Leaf litter input is expected to have a marked impact on soil physical characteristics and nutrient availability. Unlike Kwadaso, mean litter fall was significantly affected by cropping systems at Wenchi. The mean litter fall recorded under pure stand, cassava-soybean, and cassava-groundnut was not significant different while the mean value obtained under cassava-cowpea (8.9 g/m$^{-2}$) was significantly lowest among the cropping systems. Combination of water and nutrient stress might have likely induced leaf abscission resulting to greater litter fall observed among cassava-legume intercrops relative the pure stand.Kihara et al (2011) study a similar case in a soybean/maize intercrop and found that greater litter fall did not translate into greater crop yield suggesting the need to investigate effect of litter fall on soil moisture in future studies.

## Grain Yield

The results obtained for the mean grain yield of cowpea, soybean, and ground are presented in Table 13. There were no significant interactions effects on grain yield at both locations (Kwadaso and Wenchi). However, at Wenchi, the study showed that fertilizer application affected grain yield significantly. The control treatment (0 N-P2O5K2O kg/ha) recorded the highest mean grain yield of 0.6 t/hafollowed by 0.3 recorded in plots treated with 30 N-P2O5-K2O kg/ha.

Table 12: *Effect of Fertilizer and Cropping Systems onLitter Dry Matter (g/m$^{-2}$) collected under 6-12 Months Old Cassava*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 12.6 | 8.4 | 20.4 | 9.7 | 13.5 | 8.8 | 15.5 | 8.9 |
| Cassava-cowpea | 14.1 | 14.0 | 13.1 | 15.7 | 15.9 | 17.3 | 14.4 | 15.7 |
| Cassava-soybean | 15.1 | 14.4 | 15.2 | 16.1 | 16.3 | 15.9 | 15.5 | 15.6 |
| Cassava-groundnut | 15.3 | 13.8 | 15.5 | 16.9 | 15.9 | 15.4 | 15.5 | 15.4 |
| Mean for Fert. | 14.3 | 12.7 | 16.1 | 14.6 | 15.4 | 14.3 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 1.4 | 0.9 | | | | |
| Cropping systems | NS | NS | 1.6 | 1.0 | | | | |
| Fert. x CPS | NS | NS | 2.8 | 1.8 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

The lowest grain yieldof 0.2 t/ha was obtained when15 N-$P_2O_5$-$K_2O$ kg/ha was applied but did not vary significantly from the yield obtained in plots treated with 30 N-$P_2O_5$-$K_2O$ kg/ha.Nyi (2014) studied similar case at two locations in DR Congo and reported that there were no significant differences observed between treatments with NPK fertilizer and those without NPK fertilize.

The case of Wenchi implies supplied through fertilizer were not converted into pod efficiency. This could be due to the fact that application of excess nutrient was not effectively utilize by the crop. Nutrient supplied through fertilizer may have been heavily competed for by component crops or it may have resulted in luxury consumption by the legumes (Nyi, 2014). When species are in direct competition for limited resources, an increase in yield of one component causes proportionate decrease in the other crop species.

At Kwadaso, cropping systems were significant on the mean grain yield obtained. The mean reported under cassava-soybean (2.1 t/ha) was significantly higher than the mean obtained for cassava-cowpea and cassava-groundnut while the mean for cassava-cowpea was significantly higher than cassava-groundnut. There was significant variation amount intercropping systems. Cassava-groundnut gave the lowest yield of 0.1 t/ha at Kwadaso. The lower grain yield of groundnut might be attributed to the competition capacity of cassava in the intercropping system.The findings are in close conformity with the report of Pothanee et al (2001). The authors reported that cassava intercropped with soybean and cowpea was more profitable over cassava-groundnut intercrop in terms of grain yield.

Table 13: *Effect of Fertilizer and Cropping Systems on Grain Yield (t/ha) of Cowpea, Soybean, and Groundnut*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Cassava-cowpea | 1.6 | 0.3 | 1.4 | 0.1 | 1.1 | 0.2 | 1.4 | 0.2 |
| Cassava-soybean | 2.4 | 0.7 | 1.5 | 0.3 | 2.4 | 0.3 | 2.1 | 0.4 |
| Cassava-groundnut | 0.1 | 0.7 | 0.1 | 0.2 | 0.2 | 0.5 | 0.1 | 0.4 |
| Mean for Fert. | 1.4 | 0.6 | 1.0 | 0.2 | 1.2 | 0.3 | | |

| | P-VALUE | | SED | | LSD | |
|---|---|---|---|---|---|---|
| Fertilizer | NS | 0.02 | 0.35 | 0.12 | | 0.25 |
| Cropping systems | <.001 | NS | 0.35 | 0.12 | 0.7 | |
| Fertilizer x cropping systems | NS | NS | 0.61 | 0.21 | | |

NS: Non significant, Fert.: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

The combination of cropping systems and NPK fertilizer did not show significant effects on mean grain yield in this study. This might be as a result of the differences in soil fertility status in the study areas as the treatment combinations may not have sustained the soil condition suitable for optimal crop yield, leading to the over dependency of organic fertilizer which usually increase the cost of production (Anyasi & Atagana, 2014).

**Total Biomass (legumes)**

The results of this study showed that total biomass yield was not significantly affected by fertilizer treatments. Mean biomass yield at Kwadaso (Table 14) varied significantly from 1.2-10.2 t/ha among intercrop treatments. Cassava-soybean recorded the higher biomass yield relative to cassava-cowpea, and cassava-groundnut with cassava-groundnut given significantly lowest biomass yield (1.2 t/ha). Pypers et al., (2011) observed higher biomass yield when soybean was intercropped with cassava in the first and second cropping seasons relative to mono-cropped soybean under varying fertilizer regimes. According to Nyi (2014), crop species in an intercrop compete inter-specifically for resources such as space, light, moisture and nutrients which can affect biomass production. The legumes (cowpea, soybean, and groundnut) might have taken advantage of the slow early development of cassava which might not have reached the inter-specific competition for resources with the legumes.

Table 14: *Effects of Fertilizer and Cropping Systems on Total Biomass yield (t/ha) of Cowpea, Soybean, and Groundnut*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean root # for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Cassava-cowpea | 6.5 | 1.8 | 5.0 | 3.7 | 5.0 | 3.4 | 5.5 | 2.9 |
| Cassava-soybean | 9.3 | 4.1 | 10.0 | 3.6 | 11.3 | 1.4 | 10.2 | 3.0 |
| Cassava-groundnut | 1.2 | 4.6 | 1.0 | 2.7 | 1.2 | 2.5 | 1.2 | 3.2 |
| Mean root # for Fert. | 5.7 | 3.5 | 5.4 | 3.3 | 5.9 | 2.4 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 1.6 | 0.9 | | | | |
| Cropping systems | <.001 | NS | 1.6 | 0.9 | 3.5 | | | |
| Fert x CPS | NS | NS | 2.8 | 1.5 | | | | |

NS: Non significant, RT: Root, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

**Harvest Index (Legumes)**

Harvest index ranged from 15.1 to 18.5 among fertilizer treatments at Kwadaso. However, fertilizer treatments did not show significant effect on harvest index recorded for cowpea, soybean, and groundnut in this study (Table 15). Conversely, mean harvest index was significantly affected by cropping systems. The mean obtained under Cassava-cowpea was significantly higher than the mean harvest index reported for cassava-soybean and cassava-groundnut respectively. On the other hand, the mean for cassava-soybean was different from that of cassava-groundnut.

Cassava-groundnut recorded the lowest harvest index (1.7) in this study. Low crop harvest index is a major cause of less crop yield. Probably, the huge increase in the root yield of cassava might have caused a proportionate decrease in groundnut yield as they compete for growth resources (Esiape, 2015). In the case of maize-legume intercropping system in the Southern region of Nigeria, Undie, Uwah, and Attoe, (2012) reported indicated similarly that soybean intercropping gave significantly higher harvest index relative to maize-cowpea and maize-groundnut intercropping arrangement.Mean harvest index varied from 6.8 to 20.8 among fertilizer treatments while the mean observed under cropping systems ranged from 11.8 to 14.8 at Wenchi. However, mean harvest index was unaffected by fertilizer application and cropping systems.

Table 15: *Effects of Fertilizer and Cropping Systems onHarvest Index of Cowpea, Soybean, and Groundnut*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Cassava-cowpea | 25.4 | 24.7 | 27.3 | 6.3 | 21.7 | 4.3 | 24.8 | 11.8 |
| Cassava-soybean | 19.2 | 18.3 | 13.9 | 7.0 | 20.7 | 17.3 | 17.9 | 14.2 |
| Cassava-groundnut | 4.0 | 19.3 | 4.2 | 7.0 | 13.1 | 18.0 | 7.1 | 14.8 |
| Mean for Fert. | 16.2 | 20.8 | 15.1 | 6.8 | 18.5 | 13.2 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 3.3 | 5.4 | | | | |
| Cropping systems | <.001 | NS | 3.3 | 5.4 | 7.01 | | | |
| Fertilizer x cropping systems | NS | NS | 5.7 | 9.3 | | | | |

NS: Non significant, Fert.: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

## Dry Weed Biomass

The reduction of weed growth by crop interference has been documented as one determinant of yield advantage of intercropping, being viable alternative for weed management(Mobasser, Vazirimehr, & Rigi, 1970). Weed samples were collected at 4 and 8 weeks after planting to determine the effect of intercropping on the dry matter of weed biomass at Kwadaso and Wenchi study respectively. Data presented in Table 16 showed significant effect on mean dry weed biomass due to cropping systems at 4 weeks after planting. At Kwadaso, cassava-soybean intercrop recorded the lowest mean weed dry matter (40.1 g/m$^{-2}$) but did not differ statistically from the mean obtained under cassava-cowpea, and cassava-groundnut.

Cassava-soybean and cassava-cowpea recorded lower weed dry matter relative to the control (pure stand). Mean obtained under cassava-groundnut intercrop did not vary significantly from that of pure stand. Generally, the study indicated that intercropping cassava with legumes was more effective in decreasing weed density compared to pure stand. At Wenchi, it was noted that the mean weed biomass reported under pure stand was significantly higher than the mean obtained for cassava-cowpea, cassava-soybean and cassava-ground (Table 16). Cassava-soybean intercrop gave the lowest mean value for dry weed biomass but did not deviate significantly from results obtained for cassava-cowpea and cassava-groundnut. Intercrop system reduces weed growth (Tripathi and Singh, 1983; Weil and McFadden, 1991; Carruthers *et al*., 1998), thereby causing reductions in herbicide use. The mean weed biomass at 8 weeks after planting was unaffected by fertilizer application and cropping systems at Kwadaso (Table 17).

Table 16: *Influence of Fertilizer and Cropping Systems on Weed Biomass Collected at 4 Weeks after Planting*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 54.2 | 82.7 | 50.6 | 85.9 | 60.2 | 86.3 | 55.0 | 85.0 |
| Cassava-cowpea | 43.1 | 48.8 | 40.1 | 45.4 | 42.1 | 45.9 | 41.7 | 46.7 |
| Cassava-soybean | 36.4 | 37.7 | 45.1 | 28.6 | 39.1 | 32.8 | 40.2 | 33.0 |
| Cassava-groundnut | 43.9 | 54.1 | 61.3 | 55.2 | 43.2 | 69.7 | 49.5 | 59.7 |
| Mean for Fert. | 44.4 | 55.8 | 49.3 | 53.8 | 46.1 | 58.7 | | |

| | P-VALUE | | SED | | LSD | |
|---|---|---|---|---|---|---|
| Fertilizer | NS | NS | 4.8 | 4.9 | | |
| Cropping systems | 0.04 | <.001 | 5.5 | 5.6 | 11.4 | 11.6 |
| Fert x CPS | NS | NS | 9.58 | 9.7 | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference

Table 17: *Influence of Fertilizer and Cropping on Weed Biomass Collected at 8 Weeks after Planting*

| | Fertilizer levels (N-P2O5-K2O kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 15 | | 30 | | Mean for CPS | |
| Cropping systems | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Pure stand | 37.9 | 31.4 | 29.0 | 24.7 | 27 | 37.8 | 31.3 | 31.3 |
| Cassava-cowpea | 23.0 | 15.1 | 22.5 | 14.1 | 20.8 | 17.8 | 22.1 | 15.7 |
| Cassava-soybean | 20.9 | 14.1 | 29.3 | 17.5 | 25.4 | 17.2 | 25.2 | 16.3 |
| Cassava-groundnut | 25.8 | 14.2 | 28.7 | 15 | 25.1 | 21.1 | 26.5 | 16.8 |
| Mean for Fert. | 26.9 | 18.7 | 27.4 | 17.8 | 24.5 | 23.5 | | |
| | P-VALUE | | SED | | LSD | | | |
| Fertilizer | NS | NS | 2.9 | 2.5 | | | | |
| Cropping systems | NS | <.001 | 3.3 | 2.9 | | 6.1 | | |
| Fert x CPS | NS | NS | 5.7 | 4.9 | | | | |

NS: Non significant, Fert: Fertilizer, CPS: Cropping systems, SED: Standard error of difference, LSD: Least significant difference, Ě: Kwadaso, ě: Wench

The mean values at 8 weeks after planting, however, were lower than the mean values reported at 4 weeks after planting. Conversely, significant effect was observed on weed biomass at Wenchi due to cropping systems (Table 17). The mean weed biomass (31.3 $g/m^{-2}$) reported under pure stand was significantly higher the mean obtained under the intercrops. Mean weed biomass did not vary significantly among the intercrops. Performance of intercropping activity can be enhanced by low weed competition. 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).

## Conclusion

The study has established that intercropping cassava with cowpea, soybean and groundnut with amendment of three levels of NPK fertilizer did not significantly influence on cassava stem girth and plant height. However, cassava legume intercropping system significantly contributed to tuberous root yield at Kwadaso. Conversely, fertilizer amendment significantly affected root yield at Wenchi. Rotten roots were not significantly influenced by fertilizer or cropping systems. Greater proportions of non-marketable roots were recorded in fertilizer amended plots. Combined treatment effects of fertilizer and cropping system were significant on grain yield at Kwadaso. Cassava-groundnut recorded the lowest mean grain yield. At Wenchi, both fertilizer and cassava-legume intercrops significantly affected grain yield. Higher grain yields were recorded at Kwadaso relative to Wenchi.

Other important parameters including cassava leaf litter fall, and incident of weed infestation were studied. Cassava leaf litter fall reported in this study was unaffected by fertilizer and cropping systems. It is viewed that cassava litters have the potential to recycle nutrient and improve the organic matter content of soil. The use of intercropping cowpea, soybean, and groundnut with cassava offer the advantage of weed suppression and increased yield.

# CHAPTER FOUR

# EFFECTS OF CASSAVA-LEGUME INTERCROPPING ALTERNATIVES ON CHEMICAL SOILPROPERTIES IN TWO AGRO-ECOLOGICAL ZONES OF GHANA

## Introduction

Cassava (*Manihot esculenta* Crantz) is hardly grown as a sole crop. It is usually grown in association of other crops, such as maize, sweet potato, cocoyam, vegetables and legumes. In the recent time, cassava/legume mixture has gained prominence in view of the nutritional and cash benefits of legumes. Crop scientists have recommended the inclusion of legumes in crop production systems to address the problem of declining soil fertility. Previous research studies have unfolded the advantages of cassava/legume mixture, especially in improving the N content of the soil through fixation of atmospheric nitrogen (Aigh, 2007). Kurtz (2006) reported significantly higher values of yield and yield components of cassava intercropped with legumes than those of the yield components of sole cropped cassava. Although, legumes are known to fix nitrogen into the soil, research has it that the amount of N fixed depends on legume species. People *et al.* (1990) reported (73 – 354), (168 –208), (72 – 124), (55 – 168) and (40 – 65) kg N ha$^{-1}$ fixed into the soil by cowpea, pigeon pea, groundnut, and soybean respectively.

Studies by Birech and Freyer, (2007) showed increases in nitrogen content of the soil under crop rotation involving certain legumes, and under intercropping with legumes. Nitrogen (N) is the key nutrient limiting crop production under most situations. A major reason for insufficient nitrogen supply being its presence in organic form (in the soil) which must be mineralized before being used by the plants (Azam, 2001). Therefore, legumes have the capacity to harvest free atmospheric nitrogen (N2) into ammonia (NH3) with the help of root hairs invaded by specific bacteria (Rhizobium) at the expense of carbon supplied by the host plant. Thereafter, plant can transform it into useable form of plant nitrogen viz., amino acids and proteins. The process of symbiotic N2 fixation takes place within plant root nodules. Nodules that are fixing N2 will be pink to red inside (effective) and those which do not so are yellow to green (non-effective) in color (Anon., 2004).

Effective nodulation caused either by commercial inoculants or by indigenous soil-bacteria, is generally indicated by vigorous growth of the legumes (Vessey, 2002). Carel (2006) reported increases in soil available phosphorus under intercropping involving legumes after cropping, and adduced this to the mineralization of organic phosphorus, which in turn, results in the release of more phosphorus for crop use. Atilola, Alade, and Awe (2004) recommended the inclusion of tropical legumes in intercropping systems as a way of reducing loss of available phosphorus. These authors attributed the reduction in loss of available P to certain changes in micro – environment, which therefore, promoted greater mineralization of organic phosphorus.

To address the problem of poor soil fertility in cassava based farming systems, farmers have adopted intercropping, where all sort of crops are intercropped with cassava. This has led to rapid soil exhaustion and low productivity. Moreover, the use chemical fertilizers come with increasing wave of problems associated to the high cost of chemical fertilizers, as well as the detrimental effects of the application of these chemicals on environmental quality. To avert this, and to improve soil fertility, the recommendation of appropriate natural techniques of soil fertility improvement is imperative. To this end, this study was mainly envisaged to evaluate the effects of inter-planted legumes with cassava on major soil nutrients.

## Materials and Methods

The study was undertaken between 2014 and 2015 under rain-fed conditions at two locations namely, Kwadaso, ($6^o$ 40' N, $1^0$ 40' W) in the rain-forest zone, and Wenchi ($7^o$ 44' N $2^o$ 7' W) in the forest transitional savannah zone. Annual precipitation for Kwadaso is 1450 mm with peaks in June and September while Wenchi receive 1100 – 1200 mm respectively. The study was factorial experimental with three (3) levels of fertilizer and four (4) cassava based cropping systems. The treatments were arranged in randomized complete block designwith three replications. Planting materials used in this study were the same as indicated in experiment one.

## Soil Sampling and Laboratory Analysis

Initial soil characteristics of the experimental areas were determined before land preparation. Bulk soil samples were taken at three depths (0-10, 10-20 and 20-40 cm) at both locations (Kwadaso and Wenchi) prior to trial establishment and after the cassava crop was harvested. Sampling was done using auger. Soil samples were analyzed at the Soil Research Institute, Kumasi

## Sample Preparation

Prior to soil physical and chemical characterization, sampled soil were air-dried, later crushed and sieved through a 2 mm sieve. The techniques chosen and time required for the preparation of soil samples were carefully considered to minimize changes to properties of interest

## Characterization of Soil (Physical Properties)

### Particle Size Analysis

In measuring the percentages of primary soil separates, Bouyoucous hydrometer method was adopted (Day, 1965). Each sampled horizon was analyzed for its particle size distributions (i.e. clay, sand, and silt content). The weight of a beaker was taken using a weighing balance and fifty grams (50 g) of the 2 mm sieved soil was weighed into it and 20 ml of $H_2O_2$ was added to oxidize the organic matter. Hundred (100) milliliter of Calgon solution (Sodium hexametaphosphate and sodium hydrogen carbonate) was added to the mixture in the beaker and stirred. The mixture was then heated for the first sigh boiling while stirring and thereafter poured through a 53 µm sieve into a settling cylinder and topped to the thousand (1000) ml mark with distilled water. The retained material on the sieve was then washed off into a beaker and allowed to settle for 24 hours.

Water on top of the settled mixture was then poured off and heated to evaporate all moisture to obtain the dried sand fractions. After agitating the soil suspension with a plunger, the time was noted immediately. A hydrometer (ASTM 15 2H) was then placed into the soil suspension and the first and second readings recorded after 5 minutes and 5 hours respectively. Thereafter, the soil suspension in the cylinders was poured on a 53-µm sieve. Retained soil particles on the sieve was thoroughly washed with water into a beaker of known weight and dried in an oven at 105 °C for 24 hours. The oven-dried samples were then placed in a98ipette and weighed to represent the sand fraction.  The particle size distribution of each soil horizon sample was well calculated using established formulae (Day, 1965).

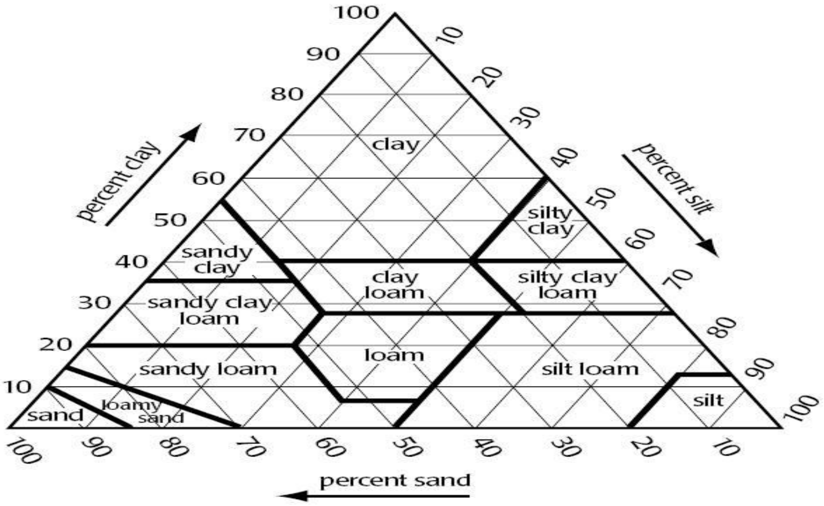


*Figure 1:* Texture triangle (Source: Soil Research Institute, Kumasi)

The texture triangle as indicated in Figure 1 was further used to determine the textural classes (primary soil separates sand, silt and clay) of each soil sample.

**Characterization of Soil (Chemical Properties)**

**Determination of Soil pH**

Twenty-five grams of soil was weighed into a 50 ml beaker. In a ratio of 1:1, 25mls of distilled water was then added. The soil suspension was then stirred for 30 minutes at 5 minutes interval. The suspension was then allowed to stand for an hour to allow the entire suspended particles to settle. A glass electrode pH meter was standardized with two aqueous solutions of pH 4 and 7. The pH of the prepared suspension was then measured and recorded by dipping the glass electrode into the soil suspension.

**Determination of Total Nitrogen**

Determining percentage total soil nitrogen involved three (3) stages; (1) digestion, (2) distillation and (3) titration. Point two (0.2) gram of air-dried soil sample was weighed into a 250 ml Kjeldahl flask followed by addition of digestion accelerator, selenium catalyst and 5 ml of concentrated sulphuric acid ($H_2SO_4$). The mixture was allowed to digest until it was clear. It was then allowed to cool and then transferred with distilled water into a 50 ml volumetric flask and made up to the mark. A 5 ml aliquot was 100ipette from the digest into a distillation flask and 20 ml of 10N Sodium hydroxide (NaOH) was added with 150 ml distilled water. The sample was then distilled and collected in 25 ml of boric acid. The distillate was then titrated against 0.02 N HCl(Bremner, 1965) to attain the end point (the point in a titration at which a reaction is complete).

The amount of nitrogen was calculated as shown below:

$$\%\,\mathrm{N} = \frac{\text{Molarity of HCl} \times \text{titre value} \times 0.014 \times \text{vol.of extractant}}{\text{Weight of soil sample} \times \text{volume of aliquot}} \times 100$$

**Determination of Organic Carbon and Organic Matter**

Wet combustion method of Walkley and Black (1934) was used to determine organic carbon. In this method, one (1) gram of soil sample was weighed and 10mls of 1N potassium dichromate ($K_2Cr_2O_7$) solution added. Twenty (20) milliliters of 98% concentrated sulphuric acid ($H_2SO_4$) was added to the prepared mixture and allowed to stand for 2 hours to ensure complete digestion. A 30 milliliters blank solution was then prepared at a ratio of 1:2 (i.e.1 ml $K_2Cr_2O_7$solution is to 2mls of $H_2SO_4$) and the blank factor determined by the following formula:

$$\textbf{Black factor (bf)} = \frac{\mathbf{10}}{\textbf{Titre value of the blank solution}}$$

Table 18: *Procedures for Calculating Organic Carbon and Organic Matter*

| A | B | C (amount of $K_2Cr_2O_7$ used) | D (Amount of CO2 evolved) | O.C. | O.M |
|---|---|---|---|---|---|
| Titre value | A x bf | 10 | C – B | D x K | O.C. x T |

Where K is a constant (0.39), T is 1.724 (i.e. there is about 58% of O.C. in O.M.), bf is the blank factor

Further on, the remaining un-reacted $K_2Cr_2O_7$in the solution after the digestion was titrated against 0.2 M ferrous ammonium sulphate using barium diphenylamine sulphonate as the indicator to give the end point. The titre value was used to calculate the % carbon and organic matter using the procedures in Table 18.

**Determination of Available Phosphorus**

Available phosphorus of the soil was determined using Bray-1 solution (Menon, Hammond, & Sissingh, 1989). Five (5) grams of soil sample was weighed into the extraction bottle and 35mls of Bray-1 solution added. It was then capped and shaken for 30 min on a mechanical shaker. The extracts were filtered using Whatman's No. 125 filter paper to obtain a clear filtrate. Five (5) mls aliquot was taken into a test tube and then ten (10) mls of colour reagent (Colour reagent was prepared from 40 grams of ammonium molybdate, 4 grams of bismuth sub carbonate, 300mls of sulpharic acid and 500 ml distilled water) added. A pinch of ascorbic acid was then added to reduce the P to form the blue colour. The mixtures in the test tubes were swirled for colour development and used for phosphorus analysis. Concentrations of P in the mixture were then determined using the spectrophotometer. Available phosphorus content of the soil was calculated as follow:

$$\text{Avail. P} = \frac{X}{0.0878} * 7$$

Where X is the absorbance and 7 is the extraction ratio (i.e. 1:7, 5 g soil: 35mls of Bray I solution).

**Determination of Effective Cation Exchange Capacity (ECEC)**

Ammonium acetate ($NH_4Oac$) pH 7.0 method was adopted to determine the CEC of the soil. To mimic field conditions, leaching tubes were used. Leaching tubes were filled with cotton and 2.5 grams of soil sample weighed into them. 50mls of $NH_4Oac$ at pH 7 was measured and poured into the cotton filled leaching tube with soil sample. The setup was allowed to stand for 2 hours to ensure maximum leaching of exchangeable bases. The leachate was then taken for elemental analysis. Here, atomic absorption spectrophotometer (AAS) was used to determine the concentrations of magnesium (Mg) and calcium (Ca) and the flame photometer was used to analyze the leachate for the concentrations of Sodium (Na) and Potassium (K).

**Determination of Exchangeable Acidity and Hydrogen**

In determining Exchangeable Acidity, as indicated by Mclean (1982), three (3) grams of soil sample was weighed in to a folded filter paper placed on an extraction cup. Fifty (50) milliliters of 1.0 N KCl solution was measured and gently poured into the soil on the filter paper for filtrate to be collected. Five (5) drops of phenolphthalein indicator was then added to the filtrate and titrated with 0.05N NaOH to obtain a pink end point. The titre volume (in mls) of NaOH used was then recorded.

The following equation was used to calculate the exchangeable acidity of the soil sample.

$$\textbf{Exchangeable acidity} = \frac{\mathbf{V * 0.05 * 100}}{\mathbf{W}}$$

Where V is the titre volume of NaOH used (ml), 0.05 is the normality of NaOH, W is the weight of soil sample in grams.

In addition, exchangeable aluminium was later determined by the addition of four (4) mls of 3*N*naF to the titrated extract and the mixture titrated again with 0.05*N*HCl to obtain a pink end point. The titre value of HCl used was the recorded and exchangeable aluminum in soil calculated using similar equation as described for exchangeable acidity.

### Determination of Nodule Number and Weight

Ten randomly selected plants were carefully uprooted at the early pod-filling stage for their nodule studies. Nodules from root of the various legume plants were picked, counted, washed, and weighed

### Data Analysis

Prior to planting, nine (9) core soil samples, randomly collected from 0 – 20 cm top –soil were mixed to form a composite, which was analysed for physical and chemical properties. At harvest, another set of composite samples was collected per plot and analysed. Analysis of variance was done for the data on fresh nodule weight, and treatment means were compared, using the Least Significant Difference (LSD) at 0.05 level of probability

### Results and Discussion

### Initial Soil Properties

Table 19 shows the soil physical and chemical properties of the soil at Kwadaso and Wenchi before trial establishment. At Kwadaso, the soil was loam in texture, with a pH of 5.6. The soil organic carbon and total nitrogen were 9.6 and 1.2 gkg$^{-1}$. The available phosphorus was 20.9 mgkg$^{-1}$. The exchangeable bases including K, Ca, Mg, and Na were 0.2, 3.4, 1.0, and 0.1 cmol kg$^{-1}$. The exchangeable acidity and effective cation exchanged capacity (ECEC) were 0.3 and 5.0 cmolkg$^{-1}$. The findings imply that the pH was moderately acidic, organic carbon was low while total soil nitrogen and exchangeable were moderate. Available P was high. Exchangeable bases,exchangeable acidity, and the effective cation exchange capacity were low.

Table 19: *The Physical and Chemical Composition of Soil of the Study Areas Prior to Trial Establishment*

| Parameters | Values | |
|---|---|---|
| | Kwadaso | Wenchi |
| Ph | 5.6 | 5.1 |
| Organic Carbon (gkg$^{-1}$) | 9.6 | 6.1 |
| Total nitrogen (gkg-1) | 1.2 | 0.1 |
| Available Phosphorus (mgkg$^{-1}$) | 20.9 | 10.5 |
| Exchangeable K (Cmolkg$^{-1}$) | 0.2 | 0.1 |
| Exchangeable Ca (Cmolkg$^{-1}$) | 3.4 | 2.0 |
| Exchangeable Mg (Cmolkg$^{-1}$) | 1.0 | 1.0 |
| Exchangeable Na ( Cmolkg$^{-1}$) | 0.1 | 0.01 |
| Exchangeable acidity (Cmolkg$^{-1}$) | 0.3 | 0.6 |
| ECEC (Cmolkg$^{-1}$) | 5.0 | 3.9 |
| Texture (gkg$^{-1}$) | | |
| Sand | 499.9 | 698.8 |
| Silt | 336.4 | 112.8 |
| Clay | 164.8 | 188.4 |

The soil texture at Wenchi was sandy loam with a pH of 5.1, indicating that the soil was acidic prior to crop establishment. The soil organic carbon and total nitrogen were low with mean of 6.1 and 0.1gkg$^{-1}$. Mean value of 10.5 mgkg$^{-1}$ shows that the initial soil available phosphorus was moderate at Wenchi. The soil exchangeable bases (K, Ca, Mg, and Na) were low. The exchangeable acidity and effective and effective cation exchange capacity were 0.6 and 3.9 cmolkg$^{-1}$.

### Changes in Soil Nutrient Status at Harvest

### Soil Organic Carbon

Data presented in Table 20 show the effect of fertilizer and cassava legume intercropping systems on soil organic carbon. Organic carbon increased under all cropping systems with or without fertilizer treatments at both Kwadaso and Wenchi. At Kwadaso, the highest increased of 31.6, 35.7, 37.5, and 39.3 % were recorded in plots without fertilizer amendment. Similar trend was observed at Wenchi where 95.1% increased in soil organic carbon was recorded under soybean-cowpea without fertilizer treatment followed by 93.4 and 90.2 % recorded in plot under cassava-groundnut and pure stand without fertilizer treatments.

Following the production of lots of cassava litter and biomass of the legumes incorporated into the plots after harvesting the legumes at three months, one would expect a commensurable increase in soil organic carbon after cropping. Moreover, the increase in soil organic carbon at harvest could be due to the fact that the cultivation of cassava may have minimized erosion and microbial decomposition rate considerably while maintaining favourable soil moisture condition. According King, Jin, and Lew(2012), regardless of decomposition rates where organic inputs outweigh organic matter losses, soil organic carbon should increase, albeit slowly.

Table 20: *Effect of Fertilizer and Cropping Systems on Soil Organic Carbon*

| | | Organic carbon ($gkg^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer (N-P2O5-K2O kg/ha) | Initial | Final | *Change | % Change | Initial | Final | *Change | % Change |
| Pure stand | 0 | 9.6 | 13.2 | 3.6 | 37.5 | 6.1 | 11.6 | 5.5 | 90.2 |
| | 15 | 9.6 | 11.3 | 1.7 | 17.4 | 6.1 | 10.3 | 4.2 | 68.9 |
| | 30 | 9.6 | 11.9 | 2.4 | 24.7 | 6.1 | 10.6 | 4.5 | 73.8 |
| Cassava-cowpea | 0 | 9.6 | 13.4 | 3.8 | 39.3 | 6.1 | 10.5 | 4.4 | 72.1 |
| | 15 | 9.6 | 12.4 | 2.8 | 29.5 | 6.1 | 10.1 | 4 | 65.6 |
| | 30 | 9.6 | 12.3 | 2.7 | 27.8 | 6.1 | 11.2 | 5.1 | 83.6 |
| Cassava-soybean | 0 | 9.6 | 12.6 | 3.0 | 31.6 | 6.1 | 11.9 | 5.8 | 95.1 |
| | 15 | 9.6 | 12.5 | 2.9 | 30.5 | 6.1 | 10.6 | 4.5 | 73.8 |
| | 30 | 9.6 | 12.3 | 2.7 | 28.4 | 6.1 | 10.9 | 4.8 | 78.7 |
| Cassava-groundnut | 0 | 9.6 | 13.0 | 3.4 | 35.7 | 6.1 | 11.8 | 5.7 | 93.4 |
| | 15 | 9.6 | 12.9 | 3.3 | 34.7 | 6.1 | 10.6 | 4.5 | 73.8 |
| | 30 | 9.6 | 12.9 | 3.3 | 34.7 | 6.1 | 11.3 | 5.2 | 85.2 |

*Change=Final-initial

## Total Soil Nitrogen

The study showed that total soil nitrogen decreased with increasing fertilizer rates under all cropping systems at Kwadaso (Table 21). The highest percentage decrease in total soil nitrogen were 16.7 for pure stand + 15- 30 N-P2O5K2O kg/ha, Cassava-cowpea + 15 N-$P_2O_5K_2O$ kg/ha, and cassava-soybean + 30 N-$P_2O_5K_2O$ kg/ha. Total nitrogen constitutes heterogeneous mixture of organic substances and is widely used as one of the main parameters for evaluating soil fertility.

Meanwhile, human activity such as fertilizer application and cropping systems play a key role in the regulation of carbon and nitrogen in agricultural soils, although in this study, total soil nitrogen decreased in treatment combinations of fertilizer and cropping systems at Kwadaso while soil organic carbon increased considerably. This might be due to higher nutrient uptake by crops than the quantity of nutrient supplied through fertilizer and legume. Conversely, contrasting increases of 800 and 900% for all treatment combinations were found at Wenchi (Table 21).

This may have been as a result of the positive impact of the applied N and the additional N fixed by component legume crops might have been shared satisfactorily among the crops thus sparing initial soil N. According Giller (2002), when grain legumes are introduced in intercrops for the first season, they could likely fix N for sharing or sparing. Another reason for the massive increase in the total soil N at Wenchi may be because of the very low initial level of N.

Table 21: *Effect of Fertilizer and Cropping Systems on Total Soil Nitrogen*

| | | Total nitrogen (gkg$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer (N-P2O5-K2O kg/ha) | Initial | Final | *Change | % Change | Initial | Final | *Change | % Change |
| Pure stand | 0 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |
| | 15 | 1.2 | 1.0 | -0.2 | 16.7 | 0.1 | 0.9 | 0.8 | 800 |
| | 30 | 1.2 | 1.0 | -0.2 | 16.7 | 0.1 | 0.9 | 0.8 | 800 |
| Cassava-cowpea | 0 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |
| | 15 | 1.2 | 1.0 | -0.2 | 16.7 | 0.1 | 0.9 | 0.8 | 800 |
| | 30 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |
| Cassava-soybean | 0 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |
| | 15 | 1.2 | 1.0 | -0.2 | 16.7 | 0.1 | 0.9 | 0.8 | 800 |
| | 30 | 1.2 | 1.0 | -0.2 | 16.7 | 0.1 | 1.0 | 0.9 | 900 |
| Cassava-groundnut | 0 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |
| | 15 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 0.9 | 0.8 | 800 |
| | 30 | 1.2 | 1.1 | -0.1 | 8.3 | 0.1 | 1.0 | 0.9 | 900 |

*Change=Final-initial

This finding is consistent with many previous studies showing the accumulating of N is the most obvious nutrient that legume intercropping and fertilizer application can significantly alter the amounts and proportion of liable and stable soil N pool (Quansah, 2010 ; Massawe, Mtei, Munishi, & Ndakidemi, 2016). The finding also support the view that integrated soil fertility management approaches such as in the inclusion of inorganic fertilizer in legume based intercropping systems is much more conductive to soil N availability (Omokanye, Kelleher, & Mcinnes, 2011).

## Available Phosphorus

Effect of fertilizer and cropping systems on available phosphorus content at Kwadaso and Wenchi are shown in Table 22. The reduction in available phosphorus at Kwadaso ranged from 64.1% to 70.8%. Pure stand with control fertilizer treatment (0 N-$P_2O_5$-$K_2O$ kg/ha) recorded the lowest reduction while cassava-cowpea plots with control fertilizer treatment reported the highest reduction in available P content. Generally, the reductions in available phosphorus content reported at Kwadaso were more than 60% under all cropping systems and fertilizer levels. The initial available P concentration at Wenchi was 10.5 $mgkg^{-1}$ and reduced considerably higher by 33.3, 39.0, 36.2, and 41.9 under pure stand + 15 N-$P_2O_5$-$K_2O$ kg/ha, cassava-cowpea + 15 N-$P_2O_5$-$K_2O$ kg/ha, cassava-soybean + 15 N-$P_2O_5$-$K_2O$ kg/ha, and cassava-groundnut + 30 N-$P_2O_5$-$K_2O$ kg/ha. The findings in this study did not conform to previous study by Aggrey (2007) who reported slight decreased in available phosphorus after cropping and concluded that cassava did not remove much P from the soil unlike nitrogen and potassium.

Table 22: *Effect of Fertilizer and Cropping Systems on Available Phosphorus*

| | | Available Phosphorus (mgkg$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer (N-$P_2O_5$-$K_2O$ kg/ha) | Initial | Final | *Change | % Change | Initial | Final | *Change | % Change |
| Pure stand | 0 | 20.9 | 7.0 | -13.9 | 66.5 | 10.5 | 7.6 | -2.9 | 27.6 |
| | 15 | 20.9 | 7.1 | -13.8 | 66.0 | 10.5 | 7.0 | -3.5 | 33.3 |
| | 30 | 20.9 | 7.1 | -13.8 | 66.0 | 10.5 | 7.1 | -3.4 | 32.4 |
| Cassava-cowpea | 0 | 20.9 | 7.5 | -13.4 | 64.1 | 10.5 | 7.1 | -3.4 | 32.4 |
| | 15 | 20.9 | 6.7 | -14.2 | 67.9 | 10.5 | 6.4 | -4.1 | 39.0 |
| | 30 | 20.9 | 7.1 | -13.8 | 66.0 | 10.5 | 7.4 | -3.1 | 29.5 |
| Cassava-soybean | 0 | 20.9 | 6.1 | -14.8 | 70.8 | 10.5 | 7.1 | -3.4 | 32.4 |
| | 15 | 20.9 | 7.1 | -13.8 | 66.0 | 10.5 | 6.7 | -3.8 | 36.2 |
| | 30 | 20.9 | 7.2 | -13.7 | 65.6 | 10.5 | 7.3 | -3.2 | 30.5 |
| Cassava-groundnut | 0 | 20.9 | 6.6 | -14.3 | 68.4 | 10.5 | 6.8 | -3.7 | 35.3 |
| | 15 | 20.9 | 7.2 | -13.7 | 65.6 | 10.5 | 6.7 | -3.8 | 36.2 |
| | 30 | 20.9 | 7.4 | -13.5 | 64.6 | 10.5 | 6.1 | -4.4 | 41.9 |

*Change = Final – initial

On the other hand, past work reported by Khan, Mulvaney, & Ellsworth (2002) indicated high response of cassava to potassium, nitrogen and phosphorus for high root yield.This study reported high cassava root yield at Kwadaso which could probably give a bitter explanation for the massive nutrients (N, P, and K) depletion observed at harvest.An experiment has indicated that the early supply of phosphorus to cassava is important and can be largely influenced by soil phosphorus and environmental conditions that affect the phosphorus phyto-availability and root growth (Grant, Bittman, Montreal, Plenchette, & Morel, 2005)

**Exchangeable Potassium**

In this study, the quantity of K removed from the soil at harvest ranged from 55-70% at Kwadaso and 10-20% at Wenchi (Table 23). The reduction in exchangeable K values observed at Kwadaso was about 50-60% more than values obtained Wenchi. This could probably be due to the high tuberous root yield achieved at Kwadaso as K is the most limited factor in cassava nutrition. Additionally, the decrease in exchangeable K can be adduced to removal by cassava and component crops. At Wenchi, exchangeable K decreased by 20% under all cropping systems and fertilizer levels except for cassava-groundnut amended with 30 N-$P_2O_5$-$K_2O$ kg/ha where 10% reduction was observed. Another factor that can be implicated for the decrease in exchangeable K is the inability of the legumes to fix appreciable quantities of K into the soil, unlike N, as the legumes are generally known for N fixation. However, the inclusion of inorganic fertilizer in the cropping systems might have contributed to the minimal decline of exchangeable K at Wenchi. It is known that fertilization is crucial for maintaining soil available nutrient levels (Dong et al., 2012).

Table 23: *Effect of Fertilizer and Cropping Systems on Exchangeable Potassium*

| | | Exchangeable Potassium (Cmolkg$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer (N-P2O5-K2O kg/ha) | Initial | Final | *Change | % Change | Initial | Final | *Change | % Change |
| Pure stand | 0 | 0.2 | 0.06 | -0.14 | 70 | 0.1 | 0.08 | -0.02 | 20 |
| | 15 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| | 30 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| Cassava-cowpea | 0 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| | 15 | 0.2 | 0.09 | -0.11 | 55 | 0.1 | 0.08 | -0.20 | 20 |
| | 30 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| Cassava-soybean | 0 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| | 15 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.07 | -0.30 | 30 |
| | 30 | 0.2 | 0.07 | -0.13 | 65 | 0.1 | 0.08 | -0.20 | 20 |
| Cassava-groundnut | 0 | 0.2 | 0.09 | -0.11 | 55 | 0.1 | 0.08 | -0.20 | 20 |
| | 15 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.08 | -0.20 | 20 |
| | 30 | 0.2 | 0.08 | -0.12 | 60 | 0.1 | 0.09 | -0.10 | 10 |

*Change = Final – initial

There is always the problem of rapid nutrient depletion under crop mixtures, due to the combined demands of the individual intercrops for nutrients (Yahaya, Adamu, Bamidele, & Moshood-Oniye, 2014). The decrease in exchangeable K at harvest was comparatively higher (30%) under cassava-soybean amended with 15 N-$P_2O_5$-$K_2O$ kg/ha at Wenchi. The indispensability of K in cassava nutrition had been demonstrated by many studies (Nyi, 2014: Pypers, Sanginga, Kasereka, Walangululu, & Vanlauwe, 2011).

### Soil pH

The initial soil pH values obtained were 5.6 for Kwadaso and 5.1 for Wenchi which imply that the soil was moderately acidic at Kwadaso and acidic at Wenchi. At harvest, the pH values vary from 6.0-6.1 under all cropping systems and fertilizer levels at Kwadaso, with a change of about 7.1-8.9%. This finding suggests that the soil was slightly acidic at harvest. Similar observation was made at Wenchi where the pH values at harvest ranged from 5.9 to 6.0 under all cropping systems and fertilizer treatments indicating that the soil was moderately acidic at harvest. The decline in pH might have resulted from the build-up of organic matter over time. Decline in soil pH can have positive impacts on availability of nutrients such as phosphorus, zinc, iron, and manganese (Singh & Kaur, 2015)

### Effective Cation Exchange Capacity (ECEC)

The effect action cation exchange capacity is the total among of exchangeable cations, which are mostly sodium, potassium, and magnesium. The ECEC decreased at harvest irrespective of fertilizer or cropping systems.

Table 24: *Effect of Fertilizer and Cropping Systems on Soil pH*

| | | Soil Ph 1:1 $H_2O$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer ( N-P2O5-K2O kg/ha) | Initial | Final | Change | % Change | Initial | Final | Change | % Change |
| Pure Stand | 0 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 15 | 5.6 | 6.0 | 0.4 | 7.1 | 5.1 | 6.0 | 0.9 | 17.6 |
| | 30 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| Cassava-cowpea | 0 | 5.6 | 6.0 | 0.4 | 7.1 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 15 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 30 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| Cassava-soybean | 0 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 15 | 5.6 | 6.0 | 0.4 | 7.1 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 30 | 5.6 | 6.0 | 0.4 | 7.1 | 5.1 | 5.9 | 0.8 | 15.7 |
| Cassava-groundnut | 0 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 15 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 5.9 | 0.8 | 15.7 |
| | 30 | 5.6 | 6.1 | 0.5 | 8.9 | 5.1 | 6.0 | 0.9 | 17.6 |

*Change = Final – initial

Table 25: *Effect of Fertilizer and Cropping Systems on the Effective Cation Exchange Capacity*

| | | Effective Cation Exchange Capacity ( Cmol $kg^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kwadaso | | | | Wenchi | | | |
| Cropping systems | Fertilizer ( N-P2O5-K2O kg/ha | Initial | Final | Change | % Change | Initial | Final | Change | % Change |
| | 0 | 5 | 4.1 | -0.9 | 18 | 3.9 | 3.5 | -0.4 | 10.3 |
| Pure Stand | 15 | 5 | 3.6 | -1.4 | 28 | 3.9 | 3.5 | -0.4 | 10.3 |
| | 30 | 5 | 3.9 | -1.1 | 22 | 3.9 | 3.4 | -0.5 | 12.8 |
| | 0 | 5 | 3.8 | -1.2 | 24 | 3.9 | 3.5 | -0.4 | 10.3 |
| Cassava-cowpea | 15 | 5 | 4.1 | -0.9 | 18 | 3.9 | 3.3 | -0.6 | 15.4 |
| | 30 | 5 | 3.9 | -1.1 | 22 | 3.9 | 3.4 | -0.5 | 12.8 |
| | 0 | 5 | 3.8 | -1.2 | 24 | 3.9 | 3.4 | -0.5 | 12.8 |
| Cassava-soybean | 15 | 5 | 3.8 | -1.2 | 24 | 3.9 | 3.4 | -0.5 | 12.8 |
| | 30 | 5 | 3.8 | -1.2 | 24 | 3.9 | 3.5 | -0.4 | 10.3 |
| | 0 | 5 | 4 | -1 | 20 | 3.9 | 3.6 | -0.3 | 7.7 |
| Cassava-groundnut | 15 | 5 | 3.9 | -1.1 | 22 | 3.9 | 3.4 | -0.5 | 12.8 |
| | 30 | 5 | 4 | -1 | 20 | 3.9 | 3.5 | -0.4 | 10.3 |

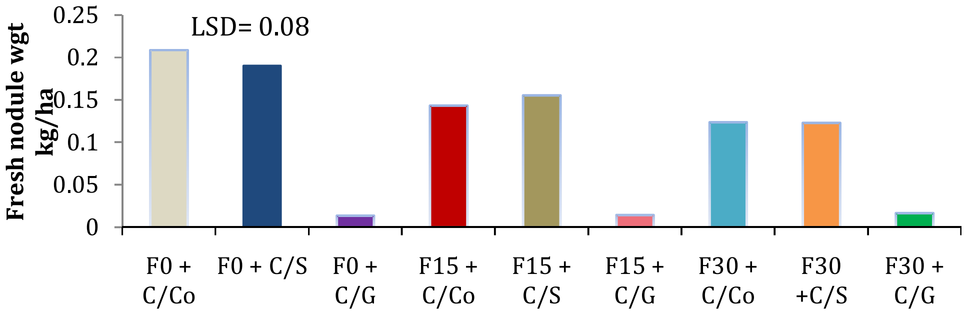
*Change=Final-Initial

The change in the ECEC values at harvest varied from 18-24% at Kwadaso and 7.7-12.8% at Wenchi. The rate of depletion of ECEC was least at Wenchi indicating that nutrients were relatively conserved as compared to Kwadaso.

**Fresh Nodule Yield**

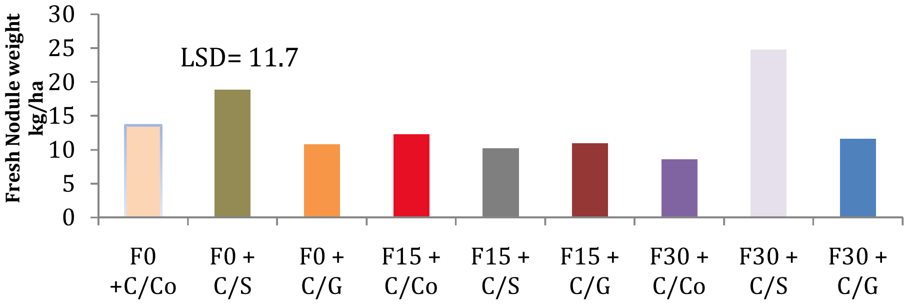
The effect of fertilizer and cropping systems on fresh nodule yield of cowpea, soybean, and groundnut intercropped with cassava at Kwadaso are presented in Figure 2. Treatment combinations of fertilizer and cropping systems significantly affected fresh nodule weight. The highest mean nodule weight of 0.21 kg/ha was reported under cassava-cowpea + control fertilizer treatment (0 N-$P_2O_5$-$K_2O$ kg/ha)but did not vary significantly from the obtained under cassava-cowpea + 15 N-$P_2O_5$-$K_2O$ kg/ha, cassava- cowpea + 30 N-$P_2O_5$-$K_2O$ kg/ha, cassava-soybean + 0 N-$P_2O_5$-$K_2O$ kg/ha (control), cassava-soybean + 15 N-$P_2O_5$-$K_2O$ kg/ha, and cassava-soybean + 30 N-$P_2O_5$-$K_2O$ kg/ha. Treatment combinations under cassava-groundnut gave the lowest mean nodule weight of 0.01 kg/ha) at Kwadaso. From the finding of this study, it is apparent that cassava-legume intercrop plots without fertilizer (control) gave higher fresh nodule weight perhaps due to optimal nitrate and ammonia conditions.

Ohyama (2011) investigated the effect of nitrate on nodule growth and nitrogen fixation in southern Japan. The author reported the highest nodule yield under zero treated plots relative to plots receiving high concentration of nitrate. Similarly, Previous study by Zerihun et al.( 2013), showed that nodule production is affected by legume varieties and fertilizer application. It has been concluded that nodule formation can be inhibited by high dose of applied N fertilizer (Kabir & Achakzai, 2007). Unkovich et al., (2008)mentioned that high nitrate and ammonia availability tend to suppress nodulation locally, while limiting nitrogen fixation systematically. This could probably explain why fertilizer control treatment recorded higher nodule weights among cropping systems.Figure 3 showed comparatively higher mean nodule yield at Wenchi relative to the result obtained at Kwadaso. However, there was no significant difference observed on fresh nodule yield due to treatments.



F0, F15, F30= 0-15-30 N-$P_2O_5$-$K_2O$ kg/ha; C/Co= cassava-cowpea; C/S= Cassava-soybean; C/G= Cassava-groundnut; LSD= Least significant different

*Figure2:* Effect of fertilizer and cropping system on fresh nodule weight of cowpea, soybean, and groundnut intercropped with cassava at Kwadaso



F0, F15, F30= 0-15-30 N-$P_2O_5$-$K_2O$ kg/ha; C/Co= cassava-cowpea; C/S= Cassava-soybean; C/G= Cassava-groundnut; LSD= Least significant different

*Figure 3:* Effects of fertilizer and cropping systems on fresh nodule weight of cowpea, soybean, and groundnut intercropped with cassava at Wenchi

## Conclusion

The results of this study have established that intercropping cowpea, soybean, and groundnut with cassava increased soil organic carbon. Total nitrogen decreased at Kwadaso, but increased under all crop combinations including pure stand cassava at Wenchi. Available phosphorus and exchangeable potassium decreased under all treatments in this study. Higher nodule weights were recorded in unfertilized plots at Kwadaso as nodulation was significantly affected by the combination effects of fertilizer and cropping systems. Conversely, treatments did nothave any influence on nodule weight at Wenchi. The study showed decline soil acidity at harvest. The decline in soil pH can have positive impacts on availability of nutrients. The ECEC decrease at harvest but the rate of decrease at Wenchi was relatively lower than Kwadaso.

# CHAPTER FIVE

# THE EFFECT OF PLANT ARRANGEMENT ON THE COMPETITIVE BEHAVIOUR OF COMPONENT CROPS

## Introduction

Intercropping is the growing of two or more crops on the same piece of land within the same year to promote their interactions and it also maximizes chances of productivity by avoiding dependence on only one crop. It is the most common crop production system in many tropical regions (Willey, 1979).There are several economic factors (Ofori & Stem, 1987) and biological as well as ecological advantages to intercropping relative for small-holder farmers (El-Swaify et al., 1998). Intercropping is the principal means of intensifying crop production and to improve returns from limited land holdings and in the tropics, cassava is often intercropped with other staple food crops (Leihner, (1983). Yield advantages resulting from intercropping may be due to component crops having different durations or growth patterns, hence, make major demands on resources at different times thereby resulting in better temporal uses of growth resources (Rao and Willey, 1980).

Cassava is a vital staple food crop in Ghana. It plays a prominent role in alleviating the food problem in the country because of its efficient productivity of food energy, tolerance of environmental stress conditions such as drought, year-round-availability and suitability for various farming systems (Makinde, Saka, & Makinde, 2007). One way to examine the competition is by comparing intercrop with sole crop yields, and this can be particularly useful if yields of different crops are put on a valid comparable basis by using some relative measure such as the land equivalent ratio and area by time equivalent ratio (Willey, 1979). Wilt (1960) introduced relative crowding as a competition function which compare, for any given species in intercrops. Suitable land area for agriculture remains fixed or is diminishing, yet farmers are faced with the task of increasing production to meet the growing demand for food. Although many crops are intercropped, legume intercropping is common because legumes have the potential of biological nitrogen fixation, which may be an important factor in conserving soil nitrogen. As mentioned in the literature some merits of intercropping include: increase in yield per land area and increase in economical returns as compared to sole crops. Yield advantages from intercropping as compared to sole cropping are often attributed to mutual complementary effects of component crops, such as better total use of available resources (Thobatsi, 2009). The need for simultaneous production of different food crops can also encourage intercropping.

The study encompasses comparison of cassava-cowpea, cassava-soybean, and cassava-groundnut intercropping practices with different planting patterns against their respective sole cropping systems. The objective was to evaluate the effect of plant arrangement on some competitive behaviors of cassava and component crops

## Materials and Methods

### Study Area

The study was conducted at the Soil research Institute, Kwadaso, and Wenchi Agri. Research Institute, Wench from April 2014 to December 2015.

### Plant Material

All planting materials were obtained from CSIR-CRI, Fumesua, Kumasi. The cassava variety used was *Essambankye.*The variety is an early maturing with the following attributes: high in starch and contain 19.8% starch depending on the environmental conditions, soil fertility and soil moisture, not easily poundable and good for flour. The varieties of the grain legumes used were *Asmodwee* (cowpea), *Nagbaa* (soybean), and *Yenyawoso* (Groundnut).

### Experimental Design and Treatments

The experiment was laid out in randomize complete block design (RCBD). The trial consisted of thirteen (13) treatments and replicated three times in three distinct blocks. The treatments consisted of three row arrangements (1:1, 1:2, and 2:1) of cassava-cowpea, cassava-soybean, and cassava-groundnut intercrops as described in Table 26. Plot size was 10 X 5m. There were 0.5m between plots and replicates. In the case of cassava, the distance between rows was 100 cm and the distance within rows was 100 cm as well. The distance from one row of cassava to a row of legume for the 1:1 arrangement was 50 cm with 20cm distance within legume row. In the 1:2 row arrangements, the distance between a row of cassava to a row of legume was 40 cm while the distance within and between legume rows remain 20cm. The distance between cassava and legume row in the 2:1 arrangements was 150 cm while the 20 cm within and between legume rows was maintained.

### Land Preparation

Land preparation was done manually with machetes and hoes since minimum tillage was used. Debris was packed and removed from the site. The field was pegged and replications were laid out as RCBD. All agronomic operations were kept uniform for the both areas.

**Data Collection:**

**Cassava**

All yield data were collected from ten (10) randomly selected plants from each plot. These plants were tagged for easy identification. Harvesting was done at 12 months after planting.

Table 26: *Cassava-Legume Row Arrangement*

| Treatment code | Treatment description |
|---|---|
| $C_1Co_1$ | Cassava- cowpea 1:1 crop arrangement |
| $C_1Co_2$ | Cassava- cowpea 1:2 crop arrangement |
| $C2Co_1$ | Cassava-cowpea 2:1 crop arrangement |
| $C_1S_1$ | Cassava-soybean 1:1 crop arrangement |
| $C_1S_2$ | Cassava-soybean 1:2 crop arrangement |
| $C_2S_1$ | Cassava-soybean 2:1 crop arrangement |
| $C_1G_1$ | Cassava-groundnut 1:1 crop arrangement |
| $C_1G_2$ | Cassava-groundnut 1:2 crop arrangement |
| $C_2G_1$ | Cassava-groundnut 2:1 crop arrangement |
| C | Cassava grown in a monoculture |
| Co | Cowpea grown in a monoculture |
| S | Soybean grown in a monoculture |
| G | Groundnut grown in a monoculture |

**Legumes**

Grain of legume crops were harvested at maturity (3-4 months after planting) in an area of 4 square meters. Yield parameter included, pod number per plot, grain weight per plot, fresh and dry Stover weight.

**Data Analysis**

Data on yield parameter of main and component crops were recorded using standard procedures and analyzed statistically using GenStat statistical package on a computer. The differences among treatment means were compared by least significant difference (LSD) test at $P= 0.05$.The competitive functions were computed in the form of relative crowding coefficient, aggressivity, competitive ratio, and land equivalent ratio.

### Relative Crowding

Relative Crowding Coefficient (K), as was reviewedby Willey (1979); measures competitive ability of crop species in a mixture. The crowding coefficient product also shows which combinations do, or do not, give a yield advantage. The equation for species *“a”* in mixture with species *“b”* was computed using the following formula:

$Kab= (Yab \times Zba)/ ((Yaa-Yab) \times Zab)$

$Kba= (Yba \times Zab)/ ((Ybb-Yba) \times Zba)$

Where;

Kab= Relative crowding coefficient for component crop “a”

Kba= Relative crowding coefficient for component crop “b”

Yaa= Sole crop yield of species a;

Ybb= Sole crop yield of species b;

Yab= Mixture yield of species a (in combination with b);

Yba= Mixture yield of species b (in combination with a);

Zab= Sown proportion of species a (in mixture with b);

Zba= Sown proportion of species b (in mixture with a)

Each species has its own relative crowding coefficient (K). If a species has a coefficient less than, equal to, or greater than one it means it has produced less yield, the same yield, or more yield than expected. The component crop with the higher coefficient is the dominant one

### Aggressivity

The aggressivity (A) shows the degree of dominance of one crop over the other when sown together. Aggressivity was calculated by the formula proposed by McGilchrist (1965):

Aab= (Yab/Yaa + Zab) – (Yba/Ybb + Zba),

Aba= ( Yba/Ybb + Zba) – (Yab/Yaa + Zab)

Where;

Aab = aggressivity value for the component crop "a".

Aba= aggressivity value for the component crop “b”

Yaa= Sole crop yield of species a;

Ybb= Sole crop yield of species b;

Yab= Mixture yield of species a (in combination with b);

Yba= Mixture yield of species b (in combination with a);

Zab= Sown proportion of species a (in mixture with b);

Zba= Sown proportion of species b (in mixture with a)

### Competitive Ratio

Competitive ratio (CR) was calculated by the formula proposed by Willey *et al.* (1980):

CRa=(Yab/Yaa x Zab) ÷ (Yba/Ybb x Zba),

CRb= (Yba/Ybb x Zba) ÷ (Yab/Yaa x Zba)

Where;

CRa = competitive ratio for the component crop “a”.

CRb= Competitive ratio for the component “b”.

Yaa= Sole crop yield of species a;

Ybb= Sole crop yield of species b;

$Yab$= Mixture yield of species a (in combination with b);

$Yba$= Mixture yield of species b (in combination with a);

$Zab$= Sown proportion of species a (in mixture with b);

$Zba$= Sown proportion of species b (in mixture with a)

### Land equivalent ratio

The land equivalent ratio (LER) was used as a criterion for measuring efficiency for intercropping advantage relative to sole cropping using similar environmental resources. When the LER is less than unity, it implies that the intercropping negatively affected the growth and yield of the species growing in the polyculture (Willey and Rao, 1980). The LER was computed using the following formula:

$LER = (La + Lb)$

$La = (Yab/Yaa)$

$Lb = (Yba/Ybb)$

Where La and Lb are the LERs for the individual crops, *Yab* and *Yba* are the individual crop yields in the intercrop while *Yaa* and *Ybb* are the individual crop yields as sole crop (Willey, 1979).

## Results and Discussion

### Root and Grain Yield

Tuberous root yield ranged from 32.9-53.8 t/ha at Kwadaso. The highest yield was recorded under sole cassava (control) while cassava-cowpea 1:1 row arrangement recorded the lowest mean. Similar observation was made at Wenchi where sole crop cassava recorded the highest root yield (34.1 t/ha). Cassava-soybean 1:2 row arrangements reported the lowest of 25.6 t/ha. However, the different row arrangements of cassava-cowpea, cassava-soybean, and cassava-groundnut did not show significant effect on mean root yield in this study(Table 27). This result is comparable to Negash & Mulualem ( 2014) who indicated that the non-significant effect of cassava-legume row arrangements on the root yield of cassava could be due to inter-specific competition between cassava and component crops. Ezumah et al. (1984) reported similar results in complex crop mixtures involving cassava/maize intercropping systems. Intercropping could result in competition for growth resources when the component crops are in intimate contact, especially with increasing planting density of any of or all the crops in the mixture (Muoneke and Asiegbu, 1997).

Grain yields of cowpea, soybean, and groundnut were unaffected by the varying row arrangements cassava-cowpea, cassava-soybean and cassava-groundnut at Wenchi (Table 27). On the other hand, there were significant differences on grain yield due to row arrangements of cassava-legume intercropping at Kwadaso. The highest grain yield (2.39 t/ha) was obtained in sole cowpea but did not vary significantly from the mean obtained in sole soybean. This could be due to the fact that the crop density in the sole crop was less and as such promotes more sunlight and other growth resources. Previous study showed that greater yield obtained in sole cropping system indicates reduction in competition for growth resources, especially nitrogen, as cowpea was probably making use of fixed nitrogen more than soil nitrogen (Njoku, 2008).

Table 27: *Effect of Cassava-Legume Intercrop Row Arrangements on Root and Grain Yields (t/ha).*

| | Root yield (t/ha) | | Grain yield (t/ha) | |
|---|---|---|---|---|
| Treatments | Kwadaso | Wenchi | Kwadaso | Wenchi |
| Cassava-cowpea 1:1 | 32.9 | 26.2 | 1.35 | 0.26 |
| Cassava-cowpea 1:2 | 46.3 | 30.0 | 0.94 | 0.04 |
| Cassava-cowpea 2:1 | 51.8 | 29.0 | 0.78 | 0.19 |
| Cassava-soybean 1:1 | 57.5 | 34.4 | 0.99 | 0.37 |
| Cassava-soybean 1:2 | 39.5 | 25.6 | 1.22 | 0.25 |
| Cassava-soybean 2:1 | 37.1 | 33.6 | 0.72 | 0.34 |
| Cassava-groundnut 1:1 | 36.3 | 28.4 | 0.22 | 0.15 |
| Cassava-groundnut 1:2 | 45.6 | 30.5 | 0.15 | 0.22 |
| Cassava-groundnut 2:1 | 45.5 | 35.2 | 0.11 | 0.19 |
| Sole cassava | 53.8 | 34.1 | | |
| Sole cowpea | | | 2.39 | 2.39 |
| Sole soybean | | | 1.97 | 0.55 |
| Sole groundnut | | | 0.36 | 0.31 |
| P-VALUE | NS | NS | <0.001 | NS |
| LSD | | | 0.9 | |
| SED | 11.4 | 4.7 | 0.4 | 0.8 |

NS: Non significant, SED: Standard error of difference, LSD: Least significant difference

There was no significant difference among sole soybean, 1:2 cassava-soybean, and 1:1 cassava-cowpea. The lowest grain yield was obtained when two rows of cassava was to one row of groundnut but did not differ statistically from the mean grain yield obtained for 1:1cassava-groundnut, 1:2 cassava-groundnuts, sole groundnut, 2:1 cassava-soybean, 2:1 cassava-cowpea, and 1:2 cassava-cowpea. The high plant density of the 2:1 cassava-groundnut might have exerted unfavourable effects on the groundnut and consequently reduced yield.

## Competitive Functions of Cassava and Component Crops

The broad effects of intercropping are mostly examined by comparing intercropping with sole cropping and this is particularly useful when different crops are put on a valid comparable basis by using some relative measures. Simple competitive ratio (CR), relative crowding (K) and aggressivity (A) are functions that attempt to measure the intercrop competition by relating yield changes (Rao &Willey, 1980). Cassava appeared to be highly dominant in all intercropping systems in this study (Table 28), as it had higher values of relative crowding coefficient (K) relative to the component crops in all row arrangements. Under all row arrangements at Kwadaso, cassava-soybean gave the highest partial *K* value (15.5) for Cassava while 2:1 cassava-soybean recorded the lowest Partial K(1.1). Partial *K* Value of 15.5 implies that one cassava plant was equivalent to 15.5 soybean plants. Probably, cassava had competitive advantage over component crops in the 1:1 row arrangement of cassava-soybean, therefore, getting the bulk of growth resources for greater root yield.

Table 28: *Relative Crowding Coefficient of Cassava and Component Crops as Influenced by Row Arrangements*

| Cropping systems | KwadasoWenchi | | | | | |
|---|---|---|---|---|---|---|
| | ( KC) | (KL) | ( K=KC x KL) | ( KC) | (KL) | ( K= KC x KL) |
| Cassava + Cowpea 1:1 | 1.6 | 1.3 | 2.1 | 3.3 | 0.1 | 0.3 |
| Cassava + Cowpea 1:2 | 12.3 | 0.3 | 3.7 | 14.6 | 0.01 | 0.1 |
| Cassava + Cowpea 2:1 | 13.0 | 0.9 | 11.7 | 2.8 | 0.2 | 0.6 |
| Cassava + Soybean 1:1 | 15.5 | 1.0 | 15.5 | 14.7 | 2.1 | 30.9 |
| Cassava + Soybean 1:2 | 5.5 | 0.8 | 4.4 | 6.0 | 0.4 | 2.4 |
| Cassava + Soybean 2:1 | 1.1 | 1.1 | 1.21 | 3.6 | 3.2 | 11.5 |
| Cassava + Groundnut 1:1 | 2.0 | 1.5 | 3.0 | 5.0 | 0.9 | 4.5 |
| Cassava + Groundnut 1:2 | 11.1 | 0.3 | 3.3 | 6.9 | 1.2 | 8.3 |
| Cassava + Groundnut 2:1 | 11.0 | 0.8 | 8.8 | 6.0 | 3.2 | 19.2 |

K: Relative crowding coefficient

KC: Relative crowding coefficient for cassava, KL: Relative crowding coefficient for legumesTotal K= KC x KL

As the product of the relatively crowding coefficient (*K*) of component crops in the 1:1 cassava-cowpea, 1:1 cassava-groundnut, and 2:1 cassava-soybean row arrangements were greater than one, implication is thatthe intercropping systems had yield advantages. Similar observation was made at Wenchi (Table 28) where partial *K* values for Cassava in all intercrop row arrangements were greater than the partial *K* values obtained for component crops which imply that cassava was the absolute dominance. Cassava-cowpea 1:2 and cassava-soybean 1:1 gave the partial K value (14.6 and 14.7) for cassava at Wenchi. Relatively crowding coefficient (K) for cassava was consistently more than one at the both study site. However, the total *K* values were greater than one except for cassava-cowpea row arrangements at Wenchi where total *K* values were less than one. Generally, cassava and component crops in the mixtures were captured more resources and were utilizing resources probably better than they did as sole crop (Keating and Carberry 1993).

**Aggressivity**

An aggressivity value of zero indicates that component crops are equally competitive. For any other situation, both crops will have the same numerical value, but the sign of the dominant species will be positive and that of dominated negative. The greater the numerical value, the bigger the differences between actual and expected yields.

Table 29*: Aggressivity of Cassava and Component Crops as Influenced by Row Arrangements*

| | Cassava-cowpea intercropping patterns | | | |
|---|---|---|---|---|
| | Kwadaso | | Wenchi | |
| Cropping systems | Aab | Aba | Aab | Aba |
| Cassava + Cowpea 1:1 | 0.0 | 0.0 | 0.7 | -0.7 |
| Cassava + Cowpea 1:2 | -0.5 | 0.5 | -0.1 | 0.1 |
| Cassava + Cowpea 2:1 | 1.6 | -1.6 | 1.8 | -1.8 |
| Cassava-soybean intercropping patterns | | | | |
| Cassava + Soybean 1:1 | 0.6 | -0.6 | 0.3 | -0.3 |
| Cassava + Soybean 1:2 | 3.1 | -3.1 | -0.7 | 0.7 |
| Cassava + Soybean 2:1 | 1.3 | -1.3 | 1.4 | -1.4 |
| Cassava-groundnut intercropping patterns | | | | |
| Cassava + groundnut 1:1 | 0.1 | -0.1 | 0.3 | -0.3 |
| Cassava + groundnut 1:2 | -0.6 | 0.6 | -0.8 | 0.8 |
| Cassava + groundnut 2:1 | 1.5 | -1.5 | 1.4 | -1.4 |

Aab: Aggressivity value for cassava
Aba: Aggressivity value for Legumes

The data shown in Table 29 revealed that component crops did not compete equally. In the cassava-cowpea and cassava-groundnut intercrop systems, cassava was dominated by legume in the 1:2 row arrangements at Kwadaso. On the other hand, the result indicated that cassava and cowpea were equally competitive in the 1:1 row arrangement. Similarly, cowpea, soybean and groundnut appeared to be more dominant at Wenchi in their respective 1:2 row arrangements, while cassava dominated the legumes considerably in the 2:1 row arrangements at the both study sites. Aggressivity value was the minimum for cowpea, soybean, and groundnut in the 1:1 row arrangement which imply that the legumes were less competitive to cassava at 1:1 row arrangement.

**Competitive Ratio (CR)**

The competitive ratio is an important tool to know the degree with which one crop competes with the other. Higher CR values for cassava than legumes except the 1:2 row arrangements of cassava-soybean at both Kwadaso and Wenchi, the study showed that under all cassava-legume row arrangements, cassava was more competitive than the legumes (Table 30). These results suggest that among intercrops, cassava proved to be a better competitor as compared to the legumes when grown in association.

Willey and Rao (1980) reported that competitive ratio (CR) gives a better measure of competitive ability of the crops in a poly-culture and can prove a better index as compared with relative crowding coefficient (K) and aggressively. Advantages from cassava-legume intercropping system have been reported by (Amanullah, Somasundaram, Vaiyapuri, & Sathyamoorthi, 2007a).

Aggressively, relative crowding coefficient and competitive ratio indicated that cassava was a dominant species in a crop mixture situation. Greater competitive ability of cassava to exploit resources in association with legume has been reported (Ogola, Mathew, & Magongwa,2013). The advantages accrued from intercropping systems, as evident from competitive functions are due to better growth resources under legume intercropping system (Ofori & Stern, 1987).

Table 30: *Competitive Ratio of Cassava and Component Crops as Influenced by Row Arrangements*

| | Cassava-cowpea intercropping patterns | | | |
|---|---|---|---|---|
| | Kwadaso | | Wenchi | |
| Cropping systems | Cassava | Legume | Cassava | Legume |
| Cassava + Cowpea 1:1 | 1.1 | 0.9 | 7.1 | 0.1 |
| Cassava + Cowpea 1:2 | 1.1 | 0.2 | 26.3 | 0.0 |
| Cassava + Cowpea 2:1 | 5.9 | 0.7 | 21.4 | 0.0 |
| Cassava-soybean intercropping patterns | | | | |
| Cassava + Soybean 1:1 | 2.1 | 0.5 | 1.5 | 0.7 |
| Cassava + Soybean 1:2 | 0.5 | 1.6 | 0.8 | 1.2 |
| Cassava + Soybean 2:1 | 1.9 | 0.3 | 3.2 | 0.3 |
| Cassava-groundnut intercropping patterns | | | | |
| Cassava + groundnut 1:1 | 1.1 | 0.9 | 1.7 | 0.6 |
| Cassava + groundnut 1:2 | 1.0 | 0.9 | 0.6 | 1.5 |
| Cassava + groundnut 2:1 | 5.5 | 0.2 | 3.4 | 0.3 |

The primary object of intercropping in this situation is to achieve full yield of the staple crop and additional yield from the second crop so that the combination giving the best yield of the second crop without reducing the yield of main crop.

**Land Equivalent Ratio (LER)**

The land equivalent ration (LER) reflects the extra advantage of intercropping systems over sole cropping systems. Table 31 contains the LER values recorded at Kwadaso and Wenchi. At Kwadaso, intercropping advantage was observed for cassava-cowpea, cassava-soybean, and cassava-groundnut in all row arrangements. According to Negash and Mulualem (2014) a yield advantage is obtained due to both temporal and spatial complementary. When the LER value is greater than one(1), it indicates an advantage of intercropping in terms of the use of environmental resources for plant growth as compared to sole cropping. Partial LER values for Cassava under all intercropping row arrangements were greater than 0.5 indicating a yield advantage for intercropping cassavaas compared to the sole cropping system. The partial LER value for cowpea, soybean, and groundnut (0.4, 0.4, 0.4) were less than 0.5 when two rows of cassava was to one row of the legumes which imply that resources were used more efficiently by the sole crops than the intercrops. These findings are also similar to Workayehu (2014) whose partial LERs for cowpea, soybean, and groundnut in a maize based intercropping systems were less than half of one (LER<0.05) . The yield advantage of intercropping systems (total LERs) probably derived from cassava in inter-specific competiveness proved that cassava is more competitive than cowpea, soybean and groundnut 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).

Partial LER values for cassava at Wenchi were greater than 0.5 indicating yield advantages for cassava intercrop relative to sole crop. The highest partial LER value was 1.0 recorded in the 1:1 cassava-soybean, 2:1cassava-soybean, and 2:1 cassava-groundnut row arrangements. The total LER obtained under 1:1 and 1:2 cassava-cowpea row arrangements was 0.9 indicating yield disadvantage to the intercropping systems relative to sole cropping. The statement is especially true for cowpea whose partial LER value was less than 0.5 in the 1:1 and 1:2 row arrangements.

Table 31: *LER of Cassava and Component Crops as Influenced by Row Arrangements*

| | Land equivalent ratio | | | | | |
|---|---|---|---|---|---|---|
| | Kwadaso | | | Wenchi | | |
| Cropping systems | Cassava | Legume | Total | Cassava | Legume | Total |
| Cassava + Cowpea 1:1 | 0.6 | 0.6 | 1.2 | 0.8 | 0.1 | 0.9 |
| Cassava + Cowpea 1:2 | 0.8 | 0.4 | 1.2 | 0.9 | 0.01 | 0.9 |
| Cassava + Cowpea 2:1 | 0.9 | 0.3 | 1.2 | 0.9 | 0.1 | 1.0 |
| | | | | | | |
| Cassava + Soybean 1:1 | 1.1 | 0.5 | 1.6 | 1.0 | 0.7 | 1.7 |
| Cassava + Soybean 1:2 | 0.7 | 0.7 | 1.4 | 0.8 | 0.5 | 1.3 |
| Cassava + Soybean 2:1 | 0.7 | 0.4 | 1.1 | 1.0 | 0.6 | 1.6 |
| | | | | | | |
| Cassava + Cowpea 1:1 | 0.7 | 0.6 | 1.3 | 0.8 | 0.5 | 1.3 |
| Cassava + Cowpea 1:2 | 0.8 | 0.5 | 1.3 | 0.9 | 0.7 | 1.6 |
| Cassava + Cowpea 2:1 | 0.8 | 0.4 | 1.2 | 1.0 | 0.6 | 1.6 |

The total LER (partial LER for cassava + partial LER for Legume) ranged from 1.0-1.7 among all row arrangements which imply that the system of intercropping cassava with cowpea, soybean and groundnut was highly productive in terms of environmental resource utilization relative to sole cropping.The values obtained for LER in this study can be closely compared to the results obtained by Esiape (2015), in a cassava-maize, cassava-soybean, and cassava-cowpea intercropping systems. The better LER values could be due to better combined intercropped yield and temporal difference which existed between the crops. It is significantly envisaged that cassava being a long season crop with an earlier slow growth rate allows it to recover from competitive effects (Amanullah, Somasundaram, Vaiyapuri, & Sathyamoorthi, 2007b).

## Conclusion

The study showed that cassava yield was not affected by the different row arrangements. However, the yield of cowpea, soybean, and groundnut was affected by the cropping systems at Kwadaso. Generally, the study reported advantages from intercropping systems relative to sole cropping. Evident from competitive functions indicate better growth resources for cassava under cassava-cowpea, cassava-soybean, and cassava-groundnut intercropping systems. Relative crowding coefficient (K) showed that the intercropping systems utilize resources more competitively especially so when one row of cassava was to two rows of legume. Cassava, however, appeared to be the dominant crop as influence by its higher values of relative crowding coefficient, competitive ratio, and positive signs of theaggressivity.Cowpea, soybean, and groundnut utilized the resources more aggressively in the 1:2 row arrangements and hence conferring their suitability as promising crops in a cassava based intercropping systems. The results obtained for land equivalent ratio in this study showed evidence of land and resource utilization for all treatments studied.

# CHAPTER SIX

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

The study has established that intercropping cassava with cowpea, soybean, groundnut and amendment of three NPK fertilizer levels (0-15-30 N-$P_2O_5$-$K_2O$ kg/ha) did not significantly influence cassava stem girth and plant height. However, cassava legume intercropping systems significantly contributed to tuberous root yield at Kwadaso, on the other hand, fertilizer amendment significantly affected root yield at Wenchi. Greater proportions of non-marketable roots were recorded in fertilizer amended plots. Combined treatment effects of fertilizer and cropping system were significant on grain yield at Kwadaso. Cassava-groundnut recorded the lowest mean grain yield. At Wenchi, both fertilizer and cassava-legume intercrops significantly affected grain yield. Higher grain yields were recorded at Kwadaso relative to Wenchi.Other important parameters including cassava leaf litter fall, and incident of weed infestation were measured in this study. Cassava leaf litter fall was unaffected by fertilizer and cropping system. The study established that intercropping cowpea, soybean, and groundnut with cassava increased soil organic carbon. Total soil nitrogen decreased at Kwadaso, but increased under all crop combinations including pure stand cassava at Wenchi. Available phosphorus and exchangeable potassium decreased under all treatments in this study. Higher nodule weights were recorded in unfertilized plots at Kwadaso as nodulation was significantly influenced by the combined effects of fertilizer and cropping systems. Conversely, nodule weights were unaffected by cassava-legume intercropping system at Wenchi. The study showed decline soil acidity at harvest. The decline in soil pH can have positive impacts on availability of nutrients. The ECEC decreased at harvest but the rate of decrease at Wenchi was relatively lower than Kwadaso. The results obtained for competitive functions indicate better growth resources for cassava under cassava-cowpea, cassava-soybean, and cassava-groundnut intercropping systems. Relative crowding coefficient (K) showed that the intercropping systems utilize resources more competitively especially so when one row of cassava was to two rows of legume. Cassava, however, appeared to be the dominant crop as influence by its higher values of relative crowding coefficient, competitive ratio, and positive sign of theaggressivity.Cowpea, soybean, and groundnut utilized the resources more aggressively in the 1:2 row arrangements and hence conferring their suitability as promising crops in a cassava base intercropping systems. The LER showed evident of land and resource utilization for all treatment studied.

## Recommendations

Based on the findings of this study, the following recommendation can be made;

i. Since cassava yield was better in the intercrops, it is recommended for farmers to do intercropping always in cassava production especially with grain legumes.
ii. There is a need for further research on complementary application of inorganic fertilizer under cassava based intercropping systems in other to improve both physical and chemical soil properties.

iii. It is recommended that, nodule counts in legumes used for the intercropped be taken into consideration in further studies to determine the reasons accounting for such yield differences at the two study sites.