KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF CROP AND SOIL SCIENCES

GROWTH AND YIELD OF HYBRID MAIZE (*Zea mays L.)* VARIETIES AS AFFECTED BY COWPEA (*Vigna unguiculata L.*) GROWTH TYPES INTERCROPPING SYSTEMS IN NORTHERN GHANA.

BY

HARUNA ABDULAI

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL

SCIENCES, FACULTY OF AGRICULTURE, IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR

MPhil Agronomy (Crop Physiology)

NOVEMBER, 2015

DECLARATION

I do declare that thesis entitled "Growth and yield of hybrid maize (*zea mays l.)* Varieties as affected by cowpea (*Vigna unguiculata l*.) growth type intercropping systems in northern Ghana" was written by me and that it contains no material previously published by another person or material nor material which has been accepted for the award of any other degree of the University. Works of other scientist are dully acknowledged.

HARUNA ABDULAI (PG.1312813) ....

Student"s Name & ID No: Signature Date

Certified by

DR. JOSEPH SARKODIE ADDO ………………………..… ………………

(Supervisor) Signature Date

DR. JAMES M. KOMBIOK ……………………......... ………………

Signature Date

(Co-supervisor)

Certified by

DR. ENOCH A. OSEKRE ……………………....… ……………...

(Head of Department) Signature Date

ABSTRACT

Self-sustaining, low-input, and energy-efficient agricultural systems in the context of sustainable agriculture have always been in the centre of attention of many farmers, researchers, and policy makers in the Northern Region and Ghana as a whole. However, most practices of modern agriculture, e.g. mechanization, monocultures, improved crop varieties, and heavy use of agrochemicals for fertilization and pest management, led to a simplification of the components of agricultural systems and to a loss of biodiversity. While modern agriculture especially hybrid seed production has brought vast increases in productivity to the world"s farming systems, it is widely recognized that much of this may have come at the price of sustainability. Restoring onfarm biodiversity through diversified farming systems such as mix cropping that mimic nature is considered to be a key strategy for sustainable agriculture by small scale farmers. To address these concerns, studies were conducted at Nyankpala in the Savanna agro ecological zone in the Northern region of Ghana involving two cowpea growth types, erect and spreading intercropped with hybrid maize to assess the influence of these intercrops on the physiological behaviour of the hybrid maize and their impact on the productivity of the system. The experiment was laid in a split plot arranged in RCBD with four replications. The main plot factor was cowpea growth type, erect cowpea (Songotra), spreading cowpea (Sanzi) and no cowpea (sole maize). The sub plot factor was maize type, which were hybrid maize varieties Pan53, Etubi, Mamaba and Obatampa (OPV). The result of soil analysis after harvesting showed that the higher the density of the cowpea biomass the better it can sustain the fertility of the soil. Generally, grain yield of sole maize (No cowpea) among the main plot factors recorded significant higher result as compared to grain yield of the two intercropping systems. The results of Benefit Cost Ratio of the cowpea/maize intercrops showed a higher ratio as compared to the result of their respective soles. The Benefit Cost Ratio of Pan 53

recorded no significant differences among the sole and its intercrops. Obatanpa, on the other hand, recorded significantly higher yield as a good material for intercropping.

ACKNOWLEDGEMENT

This is the greatest opportunity to express my profound gratitude to the Almighty for having seen me through all this far. I express my profound gratitude to my supervisors, Dr. Joseph Sarkodie Addo, Department of Crop and Soil Sciences, Faculty of Agriculture and Dr. J.M Kombiok CSIR- SARI for the invaluable supervision and constructive criticisms during the project work.

I appreciate with gratitude to Dr. S.K Nutsuga, the Director CSIR-SARI, for the moral and financial support during the project and arrangement through the WAAPP Project for financial support. I also wish to extend my sincere thanks to Dr. Alhaji Mohammed Askia for the assistance provided during the soil analysis. I am equally grateful to all senior members and my colleagues in SARI, especially Alhassan Sayibu who helped in diverse ways during the training.

My gratitude also goes to Dr. A. Larbi, Chief Scientist, Africa RISING-West Africa and Country Representative, IITA-Ghana for the financial support and the opportunity given me as a research fellow of IITA during the field work.

Finally, I wholeheartedly acknowledge my lovely wife, Rahinatu Inusah and my children for the understanding and endurance demonstrated during the period of the study.

Thank you all.

DEDICATION

This thesis is dedicated to Almighty, my late parents and all teachers both present and past) for making me what I am today.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF ABBREVIATIONS

MOFA	Ministry of Food and Agriculture
CRI	Crops Research Institute
LI	Light interception
LUE	Light Use Efficiency
PAR	Photosynthetic Active Radiation
U.S.A	United States of America
Mg	Magnesium
S	Sulphur
K	Potassium
N	Nitrogen
P	Phosphorous
OC	Organic Carbon
OPV	Open Pollinate Variety
PAN	Pannar
CORAF	Congolaise de raffinage
WECARD	West and Central African Council for Agricultural Research and Development
IITA	International Institute of Tropical Agriculture
ºC	Degree Celsius
RCBD	Randomised Complete Block Design
LER	Land Equivalent Ratio
QPM	Quality Protein Maize
CIMMYT	International Maize and Wheat Improvement Center
WAP	Weeks after Planting
DAP	Days After Planting
SARI	Savanna Agricultural Research Institute
VWC	Volumetric Water Content
LAI	Leaf Area Index
SPAD-	Special Products Analysis Division
H.I	Harvest Index
LSD	Least Significant Difference
C.V	Coefficient of Variation

CP	Cowpea
E.CP	Erect Cowpea
S.CP	Spreading Cowpea
BCR	Benefit Cost Ratio
FASID	Foundation for Advanced Studies in International Development
IFPRI	International Food Policy Research Institute

CHAPTER ONE INTRODUCTION

1.1 Background of the Study

The existence of mixed cropping systems involving mostly legumes and cereals such as cowpea and maize among small scale farmers of the West Africa Savannah regions has long been identified (Norman, 1975). Small scale farmers in Northern Ghana practise intercropping systems by using traditional combination of five to six crops. Despite the importance of intercropping, very few reports are found in the literature concerning the influences of this system on the physiology and productivity of hybrid maize. The available data refer mainly to plant water status (Wahua and Millen, 1998; Shackel and Hall, 1984; Távora and Lopes, 1990). However, it has been estimated that about 52-60 percent of small scale farmers in Northern Ghana are involved in intercropping of maize and cowpea using the local open pollinated maize varieties (MOFA 2010). Some of the reasons behind this system of cropping have been precautions against uncertainty, instability of income, and maintenance unstable soil fertility (Abalu, 1977)

Scarcity of land and erratic rainfall in Northern Ghana also put many farmers in a precarious situation, with the only practical option for ensuring food security being intercropping. The scarcity of land leads to continuous cropping, and consequent mining of the soils in term of fertility. Weeds and striga take over the fields as they can compete better than food crops in the poor soils. The best way of increasing food production includes adoption of modern varieties, practising of improved cultural techniques and following the appropriate systems. Intercropping is one of the important approach of cropping systems for increasing crop production.

Better intercrop production could be achieved with the choice of appropriate crops

(Santalla *et al., 2001*) population density and planting geometry of component crops (Myaka, 1995).

The production of hybrid maize in Northern Ghana is gaining popularity in recent years since the launch of the services of „MasaraN‟Arziki‟, an organization promoting the production of maize. In 2009, about 200,000 farmers from the three Northern regions were involved in hybrid grain maize production by using sole cropping system (Masara 2009). Private companies have also begun promoting hybrid maize varieties in Ghana. Wienco has been promoting Pannar varieties. In 2012, eight private seed companies signed a memorandum of understanding with CRI for the production of foundation and certified hybrid seeds. Under this arrangement, CRI provided breeder seeds, training and supervision to the seed companies. (IFPRI.2013)

Traditional agriculture, as practised through the centuries in Northern Ghana, has always included different forms of intercropping. Farmers grow a variety of crops, often intermingled in the same field, to sustain themselves and their families. Modern agriculture has shifted the emphasis to a more market-related economy and this has tended to favour intensive mono-cropping. Large-scale farmers in particular, have found it easier to plant and harvest one crop on the same field using machinery and inorganic fertilizers. However, small-scale farmers who do not have ready access to markets and who can normally only grow enough food to sustain themselves, recognize that intercropping is one way of ensuring their livelihood. Growing an increased number of crops helps to safeguard production from shocks such as drought and intercropping can also help to maintain the productivity of relatively fertile land.

According to Ntare (1990), farmers involved in intercropping are mostly those who practise low input farming. Intercropping in which two or more crops are grown mixed together on the same ground for all or most of their life cycle, is a wide spread traditional Africa agriculture practice (Andrews and Kassam, 1976). Intercropping of cowpea has a stabilizing effect on food security and also enhances efficiency of land use in the highly populated farming communities of Northern Ghana. Cowpea as an intercrop can contribute some residual nitrogen to the substantive crop (Willey, 1979). Grain legumes, particularly cowpea is considered to have the fewest adoption problems and is widely grown by farmers, mainly for home consumption of the seed and sometimes leaves in Northern Ghana.

1.2 Problem Statement

Sole maize cropping system introduced as a result of the hybrid maize production is a challenge to small scale farmers in Northern Ghana who normally intercrop cowpea with open pollinated maize varieties.

In this context, there was the need to conduct research to set the minds of these small scale farmers free from the outcome of intercropping cowpea with hybrid maize will be.

1.3 Main Objective

The main objective of the research was to determine the effects of intercropping cowpea on the physiological attributes of hybrid maize and their impact on the productivity of the system.

1.3.1 Specific Objectives

1. To compare the effects of intercropping hybrid and open pollinated maize with cowpea.

2. To determine the cowpea growth type suitable for maize intercrop.

3. To evaluate the effects of intercropped cowpea on weed control in maize

4. To determine the productivity of intercropping hybrid maize and cowpea

1.3.2 Hypothesis of the study

The objectives were formulated to test the null hypothesis that the two different cowpea growth types (erect and spreading) intercropped with hybrid and open pollinated varieties, lead to no differences in growth and yield of the maize. Also, it leads to no differences in the control of weeds in the crop field as against sole maize cropping.

CHAPTER TWO LITERATURE REVIEW

2.1 General Overview on Intercropping

Intercropping is the practice of cultivating two or more crop species simultaneously in proximity. It is described by Vandermeer (1989) as one option for cropping diversification. Okigho and Greenland (1976) described intercropping as the most widespread cropping system in Africa. Also, they estimated that 99% of cowpea and 75% of maize grown in Nigeria are intercropped. In North America, interest in this system is growing because of it‟s potential for increasing whole field productivity (Fortin and Pierce, 1996). Francis *et al.* (1976) estimated that 60% of maize production and most of cowpea grown in Latin America come from intercropping. Intercropping is the main cropping system in Northeast Brazil. Among the various combinations adopted by small farmers, maize and cowpea is one of the most used (Morgado and Rao, 1985).

The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. The diversification of crop systems by increasing the number of cultivated species in the same or nearby areas has been proposed by many researchers for the solution of many problems of modern agriculture. Row-intercropping, mixed-intercropping, stripintercropping and relay-intercropping are most important types of intercropping (Adu- Gyamfi et al., 2007).

Row-intercropping is the growing of two or more crops simultaneously where one or more crops are planted in regular rows, and crop or other crops may be grown simultaneously in row or randomly with the first crop. Mixed-intercropping is the growing of two or more crops simultaneously with no distinct row arrangement. Stripintercropping is the growing of two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact. Relay-intercropping involves growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest (Adu- Gyamfi et al., 2007).

According to Fukai and Trenbath (1993) the adoption of the intercropping system is usually justified by the better use of environmental resources as compared to monoculture.

In Northern Ghana, cowpea is traditionally intercropped with maize, sorghum and millet. As soon as the rains become well established in early to late June, the cereal is planted either in wider space or alternative rows. Several attempts to improve the performance in intercropping systems have been made by planting cereal and cowpea at the same time and manipulating their row spacing and densities (Norman, 1975)

Isenmilla *et al.* (1981) reported that yield losses of cowpea intercropped with maize could be reduced from 68 to 48 per cent by proper choice of cultivar. In their study on the effect of intercropping systems of cowpea growth types with maize, a cultivar known as New Era, a spreading type, sustained less damage (48 per cent yield reduction) than erect type (62.2 percent) and semi-erect type (67.7 percent).

2.1.1 Benefits of Intercropping

Some of the main benefits of intercropping are an increase in yield per area of land. Several research works have been reported on intercropping. Webster and Wilson (1996) concluded that in most of the experiments on mixed cropping in the tropics, more than one acre of pure stand was required to produce the yield of one acre of mixed crop and concluded that for the tropical small scale farmer, there was no advantage to gain by replacing the traditional practice of mixed cropping. Ezello (1996) reported that intercropping maize is one of the most popular mixed cropping combinations under rainfed agriculture in the tropics. Cultivation of maize in combination with other crops is therefore a widespread practice in Northern Ghana, most especially in the Northern Region. It is not uncommon to see crops like legumes, okra, melon, pepper and cassava being intercropped with maize. Systems that intercrop maize with cowpea are able to reduce the amount of nutrients taken from the soil as compared to maize as a sole crop.

Odhiambo and Ariga (2001) reported that with maize and beans intercrops in different ratios, production increased due to reduced competition between species compared with competition within species. Willey (1990) also considers intercropping as an economic method for higher production with lower levels of external inputs. This increasing use efficiency is important, especially for small-scale farmers and also in areas where growing season is short (Altieri, 1995). Producing more in intercropping can be attributed to the higher growth rate, reduction of weeds, reducing the pests and diseases and more effective use of resources due to differences in resource consumption (Eskandari, 2012; Eskandari *et al.*, 2009; Watiki *et al.*, 1993; Willey, 1990; Willey and Osiru, 1997). In addition, if there are "complementary effects" between the components of intercropping, production increases due to reducing the competition between them (Mahapatra, 2011; Zhang and Li, 2003; Willey, 1979).

Increased diversity of the physical structure such as leaves and roots of plants in an intercropping system also produces many benefits. Increased leaf cover in intercropping systems helps to reduce weed populations once the crops are established (Beets, 1990). Having a variety of root systems in the soil reduces water loss, increases water uptake and increases transpiration. The increased transpiration may make the microclimate cooler, which, along with increased leaf cover, helps to cool the soil and reduce evaporation (Innis, 1997). This is important during times of drought or water stress, as intercropped plants use a larger percentage of available water from the field than mono cropped plants. Beets (1990) also reported that, rows of maize in a field with a shorter crop will reduce the wind speed above the shorter crops and thus reduce desiccation.

Increased plant diversity in intercropped fields may reduce the impact of pest and disease outbreaks by providing more habitats for predatory insects and increasing the distance between plants of the same crop. Ecological benefits of intercropping include less land needed for crop production, reduction of the use of inorganic fertilizers, pesticide and herbicide use, and a reduction in soil erosion (Carlson, 2008).

Intercropping also has several benefits to the farmer including a reduction in farm inputs, addition of cash crops, diversification of diet, increased labour utilization efficiency, and reduced risk of crop failure due to uncertainties of the weather. The amount of time to plant the multiple varieties of seeds would be reduced, thus increasing labour utilization efficiency. Peak labour requirements that occur during harvest are spread out when two or more crops are harvested at different times allowing the smallholder to complete the harvest with family labour (Jension, 2006).

Intercropping presents a large level of risk reduction for the smallholder in Northern Ghana. If one crop is entirely lost to pest or drought damage, the farmer may still harvest the other crop in the field. Given the unpredictable rainy season and the different water requirements of each crop, planting many varieties of the same crop in an intercropped field gives the farmer a better chance that some crops will survive (Carlson, 2008).

One important advantage of intercropping is its ability to reduce pest and disease damage. In general, Danso *et al*. (1987) reported that strategies involved in reducing pest infestation and damage in intercropping can be divided into three groups. First is delimiter crop hypothesis in which the second specie breaks down the ability of a pest to attack its host and is used more in proprietary pests. Secondly, trap crop hypothesis, in which the second specie attract their pest or pathogen that normally does damage to the main species and is used more in general pests and pathogenic agents. Third is by natural enemies‟ hypothesis, in which predators and parasites are more attracted in intercropping, than the monocropping, and thereby diminishes parasitized and prey. Although intercropping does not always reduce pest or pathogen, most reports have pointed to reduced populations of pests and diseases in the intercropping (Fujita et *al*., 1992). In a review by Francis (1989) on intercropping, in 53% of the experiments intercropping reduced the pest, and in 18% increased the pest than the pure cropping. Increasing pests can be due to several reasons, such as the second crop is a host for pests in intercropping, or increasing the shade in canopy, provides favourable conditions for pests and pathogens activity. In addition plant residues can be as a source for pathogens inoculated as also reported by (Anil *et al*., 1998; Watiki *et al*., 1993). More species diversity in agricultural ecosystems can limit the plant pathogenic spread. Intercropping systems increases biodiversity like the natural ecosystems. This increase in diversity reduces pest damage and diseases (Anil *et al*., 1998).

2.1.2 Disadvantages of Intercropping

There have been several reports on yield reduction in mixed cropping due to competition for light, water and nutrients, or allelopathic effects that may occur between mixed crops may reduce yields (Cenpukdee and Fukai 1992a, 1992b; Carruthers *et al*., 2000; Santalla *et al*., 2001; Yadav and Yadav, 2001; Olowe and Adeyemo, 2009). Therefore selection of appropriate crops, planting rates, and changes in the spatial arrangement of the crops is necessary.

Adu-Gyamfi *et al*. (2007) reported that when nitrogen fertilizer is added to the field, intercropped cowpea uses the inorganic nitrogen instead of fixing nitrogen from the air and thus compete with maize for nitrogen. However, when nitrogen fertilizer is not applied, intercropped legumes will fix most of their nitrogen from the atmosphere and not compete with maize for nitrogen resources.

A serious disadvantage in intercropping is thought to be difficult with practical management, especially, where there is a high degree of mechanization or when the component crops have different requirements for fertilizers, herbicides, and pesticides. Additional cost for separation of mixed grains and lack of marketing of mixed grains, problems at harvest due to lodging, and grain loss at harvest also can be serious drawbacks of intercropping. Mechanization is also a major problem in intercropping. Machinery used for sowing, weeding, fertilizing, and harvesting are made for big uniform fields and not for small scale production (Lithourgidis et al., 2011).

2.1.3 Intercropping Effects on Light Interception

Light interception (LI) and light use efficiency (LUE) characterize resource capture and use efficiency of cropping systems, including cowpea maize intercrops. When cowpea is intercropped with tall cereals such as maize, light is an important factor. In field crops, there is often a linear relationship between cumulative intercepted PAR and accumulated biomass. The slope of this relationship is called the light use efficiency (Monteith, 1977; Russell *et al*, 1989). Willey (1990) reported that, improved productivity can result from either greater interception of solar radiation, a higher light use efficiency, or a combination of both. Light interception is sometimes increased as a result of growing two species together in one field, either as a result of a lengthening of the period of soil coverage which is a temporal advantage, or as a result of a more complete soil cover spatial advantage as reported by Keating and Karberry (1993). Fukai and Trenbath (1993) reported that resource use efficiency is not likely to be much affected in intercropping systems with component crops that differ in growing period, since competition between component crops is weak.

The fractions of the incoming PAR which are absorbed by canopies of component crops in intercrop systems mainly depend on leaf area index and canopy structure (Latinga *et al.*, 1999; Bastiaans *et al.*, 2000). Although these principles are well understood, Willey (1990) also reported that it is a challenge to determine light captured by component crops in intercrops. The detrimental effect of shading on cowpea in association with cereal has been reported by several researchers. Wahua *et al.* (1981) reported that, more light transmitted to cowpea, the greater its growth and yield.

2.1.4 Intercropping Effects on Soil Fertility Maintenance

Maintaining soil fertility is often one of the challenges in agriculture production. Intercropping is one of the options available to maintain soil fertility and crop yield.

According to Reddy *et al*. (1992) cowpea and maize intercropping affects soil fertility maintenance by N fixation and differential uptake by plants. After the intercrop is harvested decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop. This residual effect of the intercrop on the next crop is largest when the remains are left on the field and ploughed under after harvest. However, Giller (2001) reported that soil depletion can still occur when the nutrients taken up by the plants are not replaced with manure or fertilizers because large amount of nitrogen is removed in the grain harvested.

Intercropping system does not only provide nitrogen and other nutrients to the associated crops but also increase the amount of humus in the soil. This results in an improved soil structure reducing the need for soil tillage, whilst water loss, soil erosion and leaching of nutrients are reduced.

2.1.5 Intercropping Effects on Weed Infestation

Weed control is one of the most important aspects of food production in agricultural systems. Although appropriate selected herbicide may perform an important role in weed control, increasing weeds resistance to herbicide, high cost and especially, negative effects on environment and human life have increased the need of non-chemical weed control in agroecosystem (Augustine, 2003; Kropff, 1993; Spliid *et al.*, 2004).

All farmers weed their fields to some extent, but most of them could significantly increase their crop yields if they did a more thorough and timely job. Experiment conducted elsewhere in University of Illinois in U.S.A showed that just one pigweed every meter along the row reduced maize yields by 440 kg/ha. By the time weeds are one few centimetres tall, they have already affected crop yields in several ways. They compete with the crop for water, sunlight and nutrients. They harbour insects and also act as hosts for crop diseases. Heavy infestation can seriously interfere with machine harvesting. Few weeds like striga (witch-weed) are parasitic and can cause yellowing, wilting, loss of crop vigour and low yield (Peace Corps 1983)

Intercropping is also considered as an alternative to the use of herbicides, by reducing or suppressing weed growth as also reported by (Liebman and Davis, 2000). Kuchinda *et al*. (2003) and Olasantan *et al*. (1994) also reported that decreased weed incidence on maize by means of intercropping is dependent on several factors, such as type of maize cultivar, climatic condition of the area, sowing period, intercropped species, the type of weed and fertilizer rates. Intercropping systems might be more advantageous than mono cropping systems due to their more efficient competition for the available resources or to their allelopathic effect on weeds. Alternatively, intercropping systems might also use resources not exploited by weeds or might better convert such resources to the economic part of the crop than mono cropping would (Liebman and Dyck, 1993). Elsewhere in North-eastern Brazil, maize intercropped with cowpea (*Vigna unguiculata,* L. Walp.) is an extensively used practice, although weed has not been the main goal but rather, better utilization of environmental resources. Hence, evaluation of weed control in maize by means of cowpea intercropping is of great concern.

Intercropping generate beneficial biological effects between crops, increasing grain yield and stability, more efficient using available resources and reducing weed pressure (Jenson *et al*.; 2006; Kadziulien *et al*., 2009). Many authors have reported of limiting effect of intercropping of the number biomass of weeds (Amanullah *et al*., 2006; Banik *et al*., 2006; Carruthers *et al*., 1998; Gharinch and Moosavi, 2010; Poggio, 2005). They assigned two reasons for the reductions of weeds in intercropping systems. Some intercrop species release allellopathic compounds which limits the occurrence of weeds.

Secondly, it provides an efficient utilization of environmental resources (Eskandari and Ghanbari, 2009). Thus the growth of weeds depending on environmental resources is decreased. The main principle of efficient use of resource in intercropping depends on if crops differ in the way they utilize environmental resources. When grown together, they can complement each other and make better combined use of the resources than when they are grown separately (Ghanbari-Bonjar, 2000). Weed suppression in intercropping through more efficient use of environmental resources by component crops has also been reported (Liebman and Dyck, 1993, Mashingaizde *et al*., 2000; Mashingaidze 2004; Poggio, 2005). Intercropping patterns are more effective than monocropping in suppression of weeds, but their effectiveness varies greatly as reported by (Girjesh and Patil, 1991). Intercrops may demonstrate weed control advantages over pure cropping in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than pure cropping in usurping resources from weeds or suppressing weed growth through allelopathy. Alternatively, intercrops may provide yield advantages without suppressing weed growth below levels observed in component pure cropping if intercrops use resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than pure cropping. Because of the difficulty of monitoring the use of multiple resources by intercrop/weed mixtures throughout the growing season, identification of specific mechanisms of weed suppression and yield enhancement in intercrop systems has so far proven elusive (Matt and Dyck, 1993). In monocropping systems rarely, all available natural source such as moisture, nutrients and light are used by plant, consequently released niche are captured by the weeds. The use of resources is complementary by some plants. In this case intercropping system effectively use ecological resources and also, filling the empty niche, leads to weed control than the monocropping system (Saudy and ElMetwally, 2009; Altieri, 1995). Soria *et al*. (1975) with corn- cassava and beans- cassava intercrops reported that intercropping is effective in weed control.

2.1.6 Intercropping Effect on Economic Returns

Increased grain production per unit area of land has been reported for intercropping cowpea with maize (Quayyum *et al.*, 1987; Akanda and Quayyum, 1982). Combination of cowpea and hybrid maize in intercropping systems may increase the production and fulfil the demand for maize and legumes in Northern Ghana. A similar work was conducted on groundnut and a report of yield increase among the intercropped treatments was made. However, there have also been reports of low growing legumes often been shaded by taller cereals such as maize (Dalal, 1974; Chang and Shibles, 1985).

Under smallholder systems, low fertility conditions, poor emergence and poor growth of intercropped legume have been reported and these limit the nitrogen and organic matter contribution on farmer‟s fields to levels below the potential (Kumwenda *et al*. 1993). However, the more productive (high harvest index) grain legumes are, relatively little organic matter and N to the soil since much of the above-ground dry matter and almost all the N is removed from the field in the grain (Giller *et al*., 1994).

2.2 Maize as a Staple Food in Ghana

The majority of maize produced in Ghana is the white variety but only a little yellow maize are produced and are all used mainly for human consumption. WABS (2008) reported that about 87% of maize produced is used for local consumption. Per capital consumption continues to grow, increasing, for example, from 38.4 kilograms per head per year in 1980 to 43.8 kilograms per head per year in 2010 to 2011 which is about 14% increase (MOFA, 2011). The majority of maize produced is consumed directly by the farming households (57 percent), and the remaining production is traded either formally or informally (30 percent). A small quantity of maize is produced and used for animal feed in the poultry industry (about 13 percent). Virtually all yellow maize is imported and used for animal feed production (WABS, 2008).

2.2.1 Nutrient Requirement in Maize Production

Major nutrients required by maize for optimum growth and yield include, nitrogen (N) which is required for obtaining maximum yield and quality (Nuttall, 2012), Phosphorus (P) required particularly by the growing tips of the plant for root growth and development, Potash (Potassium K) is required in the greatest amount by maize. The assimilation of nitrogen, phosphorus and potassium reaches a peak during tasseling (Du Plessis, 2003). Maize also requires Sulphur (S) which is a constituent of protein together with nitrogen and magnesium (Mg) an essential element in chlorophyll used for photosynthesis (Anem *et al*., 2011). Maize is not very sensitive to trace element deficiencies. However, boron, copper, zinc, manganese and iron may occasionally be deficient in soils which may also affect the production.

2.2.2 Adaptation of Hybrid and Open Pollinated Maize varieties in Ghana

Adaptation simple refers to good performance with respect to yield and other agronomic characteristics in a given environment at a particular period of time (Brown and Darrah, 1985). The environment of plant includes all conditions to which it is exposed during the growth period (from pre-seedling emergence to harvest maturity). The major environmental factors are: daily maximum and minimum temperatures, soil temperature and moisture levels, humidity of the atmosphere immediately surrounding the plant, wind movement, day length, light intensity, air pollution, soil type, soil fertility, competition from other plants as neighbors, weeds and the disease-insect complex. These factors interact in a manner to produce stress on the plant. The plant"s reaction to the stress is under genetic control, and differences that exist among hybrids (Brown and Darrah, 1985). Obatampa is well adapted to the growing conditions in the lowland tropics and has been adopted extensively in Northern Ghana and many other parts of the country as well as many other African countries (Sallah *et al*., 2003). In the major season of 2012, Obatampa was by far

the dominant variety of maize and was planted in 41 per cent of maize area. It has become more popular over the years, from 16 per cent adoption in 1997 to 40 per cent in 2013. Private sector–promoted hybrids accounted for 3 per cent of maize area. Forty percent of maize area was planted with local or traditional varieties
(Aburowhoma and Ativi were the most common). The hybrid varieties are also well adapted and increasingly being adopted but were limited by the problem of economic seed production.

Obatampa, an OPV, accounted for about 96 per cent of certified seed production from 2001 to 2011 and about 2,500 tons in 2011 (3,466 tons average in 2009 through 2011). Given 0.95 million hectares cropped nationwide and an average seed rate of 20 kg per hectare, the annual certified seed production of Obatampa could cover 18 percent of the maize-cropped area with fresh seeds every year (Alene and Mwalughali, 2012).

2.2.3 The Impact of Hybrids on Maize Production

The greatest impact of hybrids on maize production could be linked or associated with the high increases in yields of maize. For example, the potential yields of Obatampa and other OPVs could be between 1.5 to 4 tons ha^{-1} of grain, while that of hybrid such as Mamaba and Pan53 could range between 6-7 tons ha^{-1} (Buah *et al*., 2009). Kanungwe (2009) also reported of hybrid potential yields above 8 tons ha^{-1} as compared to 1.5 tons ha^{-1} from the local varieties such as Dorke and Okomasa. Other attributes of hybrids includes improvement in the protein nutrition of consumers (Buah *et al*., 2009), adaptation to weeds, insects, diseases, lodging, and other stresses, the ability to increase the productivity and effectiveness of other inputs such as fertilizers, agrochemicals and labour.

Other impacts of hybrids on production were bringing changes in crop management practices such as row planting and mechanizing agriculture. Substantial investment in maize research has generated improved production technologies that have provided farmers with the means to respond to changes in demand and supply. Farmers who grow improved hybrids engage in more management practices such as increased use of fertilizer, herbicides and insecticides with greater frequency than those who grow local varieties because it brings to them the economic returns.

On the other hand, hybridization was reported to be resulting in loss of traditional maize and agricultural biodiversity of which these farmers and their ancestors have been stewards for centuries as global economic integration increases pressure on agrobiodiversity (Almekinders, 2001). Market integration promotes specialization and focus on high-yield varieties, as national markets become dominated by low- priced imports from the agricultural surpluses of the largest producers like China and USA. This led to loss of local varieties as well as minor crops, replaced local cultural traditions with modern preferences. It increased the income of hybrid producers but lowered that of local producers. Policy makers, institutions and infrastructure in the adoption of improved technologies and their impact on productivity and welfare favoured hybrid at the expense of local seeds (Doss, 2006).

In the North and Ghana as a whole, the major limitations to hybrid adoption included, insufficient seeds, high cost of seeds, inaccessibility of seeds at the onset of seasons, high cost of accompanying inputs such as fertilizers and chemicals, insufficient knowledge on the management practices, unreliable rainfall, striga problems as well as price fluctuations which failed to guarantee the return for the producers (Mawusi, 2013).

Many researchers including Monsanto Corporation projected the world population to be around 10 billion by 2030‟ and warned that low technology agriculture will not produce sufficient food to feed the world‟s growing population. They stressed that only biotechnology innovations will increase crop yields without requiring any additional farmland while maintaining valuable rainforests and animal habitats (Kimbrell, 1998).

2.3 The Impact of Cowpea Production on Farm Households

Cowpea is an important crop among the farm households of Northern Ghana. It provides a cheap source of plant protein and bridges perennial hunger gap that always exist between the time when most crops are planted and the time when major crops are harvested (Langyintuo *et al*., 2000).

The largest production is in the moist and dry savannahs of Sub-Saharan Africa, where it is intensively grown as an intercrop with other cereal crops like millet, sorghum and maize (Ishiyaku *et al*., 2010). Though it is not a staple food in the Northern regions, it is a very precious crop to those living in a marginal ecologies and resilience in withstanding poor ecological conditions. After harvesting, farmers store and sell more than 60% of the produced cowpea when prices go up during the off season (CORAF/WECARD Cowpea 2011). The crop is high in food and fodder values which makes it a commodity that can turn around the fortunes of small holder farmers. Nutritionally, its protein content is high to as much as 25-30% (Boukar *et al*., 2001).

CHAPTER THREE MATERIALS AND METHODS

General details of the experiments carried out at both on- station and on- farm at Savanna Agricultural Research Institute experimental site and Dipali farming community respectively are presented in this chapter. Experimental designs, treatment allocations and general procedures followed in the collection of data from crop parameters, soil and in the laboratory are also presented.

3.1 Description of Experimental Site

The experiment was conducted on-station at Savanna Agricultural Research Institute research fields at Nyankpala. It was also replicated on-farm at IITA intervention community, Dipali, in the Northern region. Nyankpala and Dipali communities are both located within the Northern savannah Agro-ecological zone of Ghana which are 16km and 17km west and north of Tamale respectively.

3.1.1 Climate of Experimental Sites

The climate of the areas is warm, semi-arid tropical and has a mono-modal annual rainfall of 800-1200mm, which mostly occurs between May/June to October. The variability of rainfall ranges between 15-20% within the area which sometimes has a negative impact on agriculture production in the region. The dry season occurs mostly between October and May and is characterised by harmattan winds.

Atmospheric temperature is relatively high, ranges within a minimum of 26ºC in December and January during the harmattan to a maximum of 39ºC in March. The annual mean of 32 ºC is recorded in the rainy season.

Relative humidity also ranges from 65%-85% and in the wet season it can be as high as 100% and as low as 10% in the harmattan period.

Table 3.1 Climatological Data at Nyankpala during Experimental Period (June-October 2014)

Month	Sun shine (hrs)	Total rainfall/ Month (mm)	Total Evaporation (mm)	Wind speed (km/hr)	Mean Rel. humidity (%)	Min.Temp (ºC)	Max. Temp (ºC)

June July August September October	7.0 6.0 5.1 5.2 8.0	166.5 122.9 240.0 195.6 153.1	117.08 97.24 77.98 80.52 98.20	3.70 2.57 2.06 1.23 0.80	76 81 83 84 79	25.6 24.9 23.3 23.1 23.5	33.2 30.9 30.4 30.5 32.7

Source: CSIR- SARI Meteorological station

3.1.2 Vegetation of the Experimental Sites

The vegetation of the sites is mainly grassland interspaced with shrubs and trees such as Shea (*Vitellaria paradoxa*) and *Parkia biglobosa* commonly known as *Dawadawa*.

3.2 Experimental Design and Treatments

3.2.1 On - Station Experiment

The field experiment was laid in a split plot design arranged in RCBD with four replications. The main plot factor was cowpea growth type, which were erect cowpea (Songotra), spreading cowpea (Sanzi) and no cowpea (sole maize). The sub plot factor was maize type, which comprised of hybrid maize varieties, Pan53, Etubi, Mamaba and the OPV, Obatanpa.

3.2.1.1 Field Layout and Plant Spacing

The main plot size was 21 x 5m with 1.5m alley between each main plot which gave an area of 105 m^2, while the sub plots size was 5 x 4.5 m within the main plot with an alley of 1m which gave an area of 22.5 m^2 planted with six rows of maize intercropped with 5 rows of cowpea. The planting distance of the maize was 75 x 40 cm with two plants per stand which gave a plant population of 150 per plot and 66,666 per hectare. The planting distance of the cowpea was 20 cm apart between each two rows of maize with two plants per stand which gave a plant population of 250 per plot and 133,333 per hectare, respectively.

3.2.2 On - Farm Experiment

The same experiment was conducted in an IITA intervention community, Dipali, in the Savelugu/Nanton District of the Northern Region in a form of on-farm experiment, for the involvement of farmers in the evaluation of the cropping system. Each farmer was considered as a replicate. In all ten farmers were involved out of which the best four were used for the evaluation. All farm practices were carried out together with the farmers. The experimental design was RCBD with the same treatment as the on-station but with an inclusion of sole cowpea for the determination of LER and Economic returns of the farmer.

3.3 Land Preparation and Planting

Pre-plant land tillage was done by the conventional land preparation method of both ploughing and harrowing. Field layout and pegging was then carried out with the appropriate plot size. Finally, sowing was done on the 18th and 30th of July for both maize and cowpea respectively. The planting distance was 75 x 40cm for the maize and 75 x 20cm for the cowpea.

3.3.1 Planting Materials

Seeds of both maize and cowpea varieties were obtained from IITA (Africa Rising) office in Tamale. The maize varieties were medium duration with white as the seed colour. The varieties were PAN 53, Etubi, Mamaba and Obatampa. The cowpea varieties were Songotra (erect variety) and Sanzi (spreading variety).

Pan 53 is one of the Pannar hybrid varieties from South Africa with a white seed colour. It is a medium duration variety and has a potential yield of 6-7 tons per hectare. Etubi is a QPM hybrid which is drought and lodging tolerant with a potential yield of 6.5-7 tons per hectare. It was released by CIMMYT in 2007. Mamaba is a hybrid released in 1996 by CIMMYT. It is a high yielding and drought tolerant variety but lodges heavily in certain conditions. It has a potential yield of 6-7 tons per hectare. Obatampa, on the other hand was released as a medium-maturing open-pollinated QPM variety in 1992 by IITA/CIMMYT. However, it is still by far the most popular variety with a potential yield of 4.6 tons per hectare. It is adapted to the growing conditions in the lowland tropics and has been adopted extensively in Ghana and many other African countries.

Songotra is an erect type of cowpea with a white seed colour, released by IITA in 2008 and it has a yield potential of 600 kg/ha (on-farm), while Sanzi is a spreading type of local variety with a yield potential of 400 kg/ha (on-farm).

3.4 Cultural Practices

3.4.1 Weed Control

Manual hand hoeing started at three weeks after planting. Weed score, count and dry matter were done at each weeding stage. A meter square quadrat was used randomly at four locations in each plot to score using zero for not weedy, one for moderate, two for weedy and 3 for very weedy. After harvesting of the maize, the weeds were also harvested at ground level, oven dried at 65 ^{o} C for 72 hours and dry weight determined.

3.4.2 Fertilizer Application on Maize Plants

Compound fertilizer, NPK (15, 15, 15) was applied to the maize as basal fertilizer at a rate of 60 kg N/ha., 60 kg P/ha., and 60 kg K/ha at 3 WAP. Top-dressing with Sulphate of ammonia was then carried out at 6 WAP at 50 kg N/ha.

3.4.3 Insecticide Application on Cowpea Plants

Lambda 2.5 E.C (Active ingredient, Lambda-cyhalothrin) was applied to protect the cowpea against field pest at a rate of 600ml ha^{-1} 3WAP. This was repeated at the 5th and 7th WAP.

3.5 Field Data Collection

3.5.1 Soil Sampling and Analysis

An auger was used to take five representative soil samples on the experimental field at a depth of 0-15cm and 15-30 from each replication. The soil samples were taken in a zigzag way across each replication (Smith and Atkinson, 1975). Samples were then bulked together and prepared for analysis for initial soil status at the start of the experiment.

The second sampling followed similar procedure as in first sampling above, but across treatments just after harvesting to assess which and how much nutrient was left as residue in the soil.

The soil samples were air-dried crushed and passed through a 2-mm sieve. Gravel, stones, non-decomposed plant parts were all discarded. Samples were then stored in polythene bags for chemical and physical analysis.

Soil analysis was done in the Soil Science laboratory of the Savanna Agricultural Research Institute, Nyankpala for N: P: K., organic carbon content and pH.

3.5.2 Soil Total Nitrogen Determination

Soil total nitrogen was determined by Kjeldahl method, which involves digestion, distillation and titration. This involved the digestion 1g of soil sample in 5ml concentrated sulphuric acid and a few drops of 30% hydrogen peroxide added to it with selenium as catalyst. With this method, organic nitrogen was converted to ammonium sulphate and the resultant solution made alkaline by addition of 5ml of 40% sodium hydroxide and ammonia distilled into 2% boric acid and titrated with standard hydrochloric acid.

3.5.3 Available Phosphorus Determination

Available phosphorus was determined by using 20ml of Bray‟s P1 extracting solution in addition to 2.0g of soil in 50 mills bottle. This was well shaken and filtered into a 100ml flask. 10 mill of the filtrate was then pipetted into a 25 mills flask. Each 1ml of molybdate agent and reducing agent was added with distilled water to a mark of 25 mills. This was followed by vigorous shaking and allowed to stand undisturbed for about 30 minutes for colour development. Measurement of percentage transmittance was done on a spectrophotometer.

3.5.4 Determination of Soil pH

Hydrogen ion concentration (pH) of the soil sample was determined at the SARI laboratory. With this, 10g air dried soil was put in a 100 mills beaker. A 25 mills of distilled water was added and vigorously stirred for about 20 minutes. It was then allowed all suspensions to settle. Electrode of pH meter was inserted into the suspension and reading taken (Motsara and Roy, 2008).

3.5.5 Determination of Organic Carbon

Percentage of organic carbon was determined by weighing 2g of the soil sample in 500ml flash. In a burette, 10 mills of 1.0 N potassium dichromate was added. Also, 20 mills of conc. H_2SO_4 were added. The mixture was then allowed to cool for 30 minutes. After which 200ml of distilled water and 10ml of orthophosphoric acid was added and titrated with 1.0 N ferrous sulphate solution (Walkley and Black, 1934).

3.5.6 Volumetric Water Content (VWC)

Volumetric water content is a numerical measure of soil moisture. It is the ratio of water volume to soil volume. Soil consists of three main constituents, mineral particles (sand, loam, or clay), water and air. Air and water which occupy the pore space typically make up approximately 50% of the soil by volume and the remaining mineral particles also 50%. As a result water content ranges from 0-50%. Campbell Hydro sense II (Scottech, USA) was used to measure VWC of the soil. It is a portable handheld device for easy soil moisture measurement. A rugged probe which is 20cm was inserted into the soil at five different locations in each plot and the average obtained.

3.6 Measurement of Plant Parameters

The various parameters and the methods used in their measurements are as follows;

3.6.1 Seedling Emergence

Number of plants on each plot was counted two weeks after planting to assess the plant emergence percentage. Each plot had six rows with an optimum of 24 plants per row. The number emerged was expressed as a percentage over the optimum. Where emergence was less than 75%, refilling was carried out. This was estimated as follows;

PE = NE/EN x 100

Where PE = percentage emergence

NE = Number emerged

EN = Expected number of emergence per plot

3.6.2 Plant Height

Five plants were randomly selected and tagged from the inner rows for height measurement. Their heights were taken at two weeks interval starting from 4WAP. The first measurement was done using a field measuring tape after which a meter rule was used to continue until

10 WAP, when all plants were at their full heights. The average was obtained as the height of plants for each plot or treatment.

3.6.3 Number of Leaves per Plant

Leaves count was carried out on the tagged plants at two weeks intervals from the fourth to the tenth week. The leaves of five plants were counted and the mean determined.

3.6.4 Light Interception (PAR) and LAI

A canopy analyser (AccuPAR model LP-80 PAR/LAI Ceptometer-Decagon Device, Pullman, Washington, USA) was used for the measurement of Photosynthetically Active Radiation (PAR). It is the radiation in the 400 to 700 nanometre (nm) waveband and represents the portion of the spectrum which plants use for photosynthesis. This instrument automatically records the amount of light above and beneath the crop plant and can convert these readings to give Leaf Area Index (LAI) for the plant canopy. LAI is defined as the area of leaves per unit area of soil surface. It is a valuable measurement in helping to assess the canopy density and biomass. An external PAR sensor is provided with the AccuPAR to allow simultaneous above and below canopy PAR measurements. Measurements were made across the rows by placing the one meter bar of the ceptometer beneath the plants at four locations on each plot. The external PAR sensor reads direct radiation while the bar beneath the plant canopy reads the radiation that is not captured by the plants. The difference between the two readings is the PAR captured by the plants.

3.6.5 Chlorophyll Content Determination (SPAD Value)

SPAD 502 plus chlorophyll meter (Minolta co., Ltd. Japan) which instantly measures the chlorophyll content of plant was used. Chlorophyll is the green pigment that allows plants to photosynthesize. This process use sunlight to convert carbon dioxide and water into the building blocks of plants. The SPAD value of all the leaves of the five randomly selected plants were taken from each plot and the mean determined.

3.6.6 Maize Root Lodging

The number or percentage of plants that have their root lodged at maturity. Lodged plants were counted per plot and expressed as a percentage.

3.6.7 Days To 50% Flowering

Number of days from planting to tassel or flowering and number of days from planting to silk formation was measured in each plot.

3.6.8 One Hundred Seed Weight

The harvested crops of both maize and cowpea were shelled and sun dried to 12% moisture level after which 100 seeds were randomly selected from each treatment and their weights determined.

3.6.9 Shelling and Threshing Percentages

Ten random ears from each plot were weighed and shelled. The shelling percentage was then determined by dividing the weight of the shelled grain over that of the ears and expressed as a percentage. The threshing percentage of the cowpea was also determined after threshing the pods by dividing the grains over the pods and expressed as a percentage.

3.6.10 Grain Yield

The grain yield per plot for each treatment was determined from two middle rows with an area of 7.5 m^2 and then converted into kilograms per hectare. Before that was done, plant count, number of ears or pods, number of grains per ear or pod was taken. Shelling percentage of eighty one and a grain moisture percentage of twelve was used to avoid bias estimation of yield. The grain yield was then calculated as follows;

Grain yield (kg/ha.) = Net plot grain yield (kg) x ha. (m^2) / net plot (m^2)

Grain yield (kg/ha.) = Net grain kg x 10,000m^2 / 7.5 m^2

3.6.11 Total Dry Matter

Total dry matter was also determined by harvesting and weighing the biomass of the net middle two rows with a known area and extrapolated into a hectare.

3.6.12 Plant Harvest Index

Two useful terms used to describe the partitioning of dry matter by the plant are the biological yield and the economic yield. The term biological yield represents the total dry matter accumulation of the plant system while, the economic yield have been used to refer to the volume or weight of those plants that constitute the product of economic or agriculture value. Harvest index (H.I) therefore, is the proportion of the biological yield that represented the economic yield. This was determined by summing up both the economic yield and the stover of two middle rows, excluding the roots to obtain biological yield. Harvest index was then expressed as; Economic yield/ Biological yield x100.

3.6.13 Land Equivalent Ratio (LER) of Farmers Yield

In order to study the competition effects of the crops and to evaluate the intercrop performance against the sole crops, the competition function know as Land Equivalent Ratio (LER) was calculated. It is an accurate assessment of the biological efficiency of the intercropping situation for informed decision making.

Land equivalent ratio of the maize as affected by the cowpea intercropping systems were calculated by expressing the intercrop grain yield as a ratio of the sole maize grain yield as described by Mead and Willey (1980) as follows;

$$LER = La+Lb = Ya/Sa + Yb/Sb$$

Where;

La and Lb are the partial LER or crop species a and b respectively

Ya and Yb are the individual crop yields in the intercrops.

Sa and Sb are their sole crop yields.

The total LER was the addition of the partial LERs of the two component crops.

3.6.14 Economic Returns in Farmer's Field

Farmers would like to choose and adopt an alternative method or practice if the net benefit is higher than what he or she is currently using. It is therefore very necessary to compare the extra costs with the extra benefits of the new treatments. Partial budgeting is a method of organizing experimental data and information about various alternative treatments carried out (Kombiok, 2004)

The cost of all the variable inputs and seasonal average operational cost that prevail in the study area of the cropping season on all the treatments were considered. Variable cost included amount paid by farmers for land preparation, planting, cost of materials such as seed, labour for weeding, harvesting and carting of farm produce to the house. The value or net return per hectare for each treatment was then calculated as the difference between the gross income and total cost of production. Average net returns were calculated as the mean of the annual net returns over the study period. There was not charges on capital cost such as land, interest on capital, depreciation on farm equipment and other overheads. The benefit ratio of the various treatments was calculated as the net benefit divided by the operational cost (Kombiok, 2004). The treatment that produced the highest net returns among the cropping systems would be considered by the farmers as the most profitable.

Net benefit = Gross returns – total variable cost of production

Benefit cost=_Net benefit/Total variable cost

3.7 Data Analysis

Data collected was subjected to statistical analysis using Statistical analysis program/software (Statistix, 2010). The analysis of variance procedure for split-plot was followed to determine whether there were differences among treatments. All treatments were compared using the Least Significant Difference (LSD) at 5% probability level.

Plate 1.Vegetative Growth of Maize intercropped with spreading type of cowpea

Plate 2. Vegetative Growth of Maize intercropped with erect type of cowpea

Plate 3 Vegetative Growth of Sole maize

CHAPTER FOUR RESULTS

4.1 Initial chemical properties of the soil

The result of initial soil chemical properties of the soil at study site is presented in Table 4. The soil identified as Tingoli series is a deep well drained, red in colour and acidic in reaction with thin brown granular and humus-stained topsoil overlying a thick red, gravely sub-soil. These soils occur mostly in northern Ghana. They are shallow to plinthite and low in organic matter. Soil fertility is generally poor. They have high P fixation due to the presence of abundant iron concretions.

Table 4.1 Initial soil sample analysis

pH H_2O (1:2.5)	OC (%)	Total N (%)	Available P (mg/kg)	Exchangeable K (mg/kg)
4.93	0.351	0.052	6.667	0.109

Depth 0-30 cm

4.2 Soil Nutrient Dynamics after Harvest

Treatments applied had significant effects on soil pH, OC (%), available P and exchangeable K after harvest (Table4.2). Soil pH in plots where there was no cowpea was significantly higher than the other treatment. Soil pH in the spreading cowpea plot was significantly lower than that of the erect cowpea treatment. Soil % OC was greatest in the erect cowpea treatment and this was significantly higher than all other treatment. The treatment effect of the spreading cowpea was also higher than the no cowpea treatment effect. Soil N was not significantly affected (P>0.05) by the cowpea type. Soil P and K in the no cowpea treatment was the greatest which was significantly higher than the other treatment effects, followed by the spreading cowpea treatment while the erect cowpea treatment effect was the least.

Apart from percent organic matter, the maize type did not significantly affect the soil properties. Soil organic matter under the Obatanpa variety was significantly higher than those of Pan 53 and Etubi varieties. All other treatment effects were similar.

Table 4.2 Soil pH, OC, N, P and K as affected by cowpea intercrops (0-30)

Treatments	pH H_2O (1:2.5)	OC (%)	Total N (%)	Available P(mg/kg)	Exchangeable K (mg/kg)
Cowpea type)					
Erect cowpea	4.77 4.58	0.74 0.47	0.07 0.06	3.42 5.60	0.095
Spreading cowpea	4.97	0.35	0.06	6.67	0.105
No cowpea					0.110
	0.01	0.01	NS	0.01	
LSD (0.05)	0.17	1.39	11.33	0.61	0.001
C.V (%)					0.003
Maize varieties	4.78 4.78	0.51 0.51	0.06 0.06	5.23 5.23	
Pan 53	4.78	0.52	0.06	5.23	0.104
Etubi	4.78	0.53	0.06	5.23	0.102
Mamaba					0.104
Obatampa (OPV)	N.S	0.01	NS	NS	0.103
	0.14	2.01	15.01	0.20	
LSD (0.05)					NS
C.V (%)					0.005

4.3 Maize Plant Height

Maize height increased with time and almost doubled between the first and second periods of measurements (Table 4.3). Cowpea type did not significantly affect maize plant height at 4 and 6 WAP samplings. At both 8 and 10 WAP, plant height in the no cowpea plots were the greatest, but this was only significantly higher than the erect cowpea treatment. The effects of the two cowpea type treatments were similar. Maize variety significantly affected plant height on all sampling days, except at 6 WAP. On all days, plant height of Pan 53 was the greatest, and this was significantly higher (P< 0.05) than those of Etubi and

Mamaba varieties. At 8 and 10 WAP, Obatampa plants were significantly taller than those of Etubi and Mamaba varieties.

Table 4.3 Height of maize as affected by cowpea intercrops

Treatments	Plant height (cm)			
	4WAP	6WAP	8WAP	10WAP
Cowpea type				
Erect cowpea	35.31	81.20	148.25	151.25
Spreading cowpea	35.89	86.08	153.41	156.41
No cowpea	34.83	88.38	157.05	160.05
LSD (0.05)	N.S	N.S	7.92	7.92
C.V (%)	12.01	30.96	5.99	5.81
Maize varieties				
Pan 53	39.04	89.75	168.40	171.40
Etubi	33.11	80.31	144.46	147.46
Mamaba	34.04	85.08	135.96	138.96
Obatampa(OPV)	35.18	85.73	162.79	165.79
LSD (0.05)	4.05	N.S	9.41	9.42
C.V (%)	13.67	17.62	7.35	7.21

4.4 Maize Leaf Area Index (LAI)

Results of LAI of maize are presented in Table 4.4. The results showed that at 4 WAP there were no significant differences among both main plots and sub plots factors. At 6, 8 and 10 WAP, the no cowpea treatment effect was the greatest, and this was significantly higher ($P<0.05$) than both cowpea treatments at 6 WAP, but only the erect cowpea treatment at 8 and 10 WAP. Among the levels of the sub plot factor, the treatment effect of Pan 53 variety was significantly higher than all other treatment effects on all sampling days. Treatment effects of Mamaba, Etubi and Obatanpa varieties were similar at 6, 8 and 10 WAP.

Table 4.4 LAI of maize as affected by cowpea intercrops

Treatments	LAI of maize			
	4WAP	6WAP	8WAP	10WAP
Cowpea type				
Erect cowpea	1.88 2.32	3.26 3.40	3.92	2.78 2.98
Spreading cowpea	1.99	3.85	4.12	3.39
No cowpea			4.54	
	NS	0.25		0.58
LSD (0.05)	34.12	8.29	0.58	22.01
C.V (%)			16.02	
Maize varieties	2.38	3.96 3.25		3.58 2.81
Pan 53	2.11	3.40	4.72	2.88
Etubi	1.96	3.41	3.95	2.94
Mamaba	1.81		4.02	
Obatampa(OPV)		0.24	4.08	0.29
	NS	8.18		11.58
LSD (0.05)	32.98		0.30	
C.V (%)			8.43	

4.5 Photosynthetic Active Radiation (PAR)

Results of sun light interception by maize presented in Table 4.5 showed that there was an increase in light interception from 4WAP to 8WAP after which it declined both in the main factor and the sub factor. However, there were no significant differences among levels of the main factor at 4 WAP and 6 WAP ($P>0.05$). But in the 8 WAP, sole cowpea recorded significant lower light interception as compared to the other two main factors ($P<0.05$). At 10 WAP, the spreading cowpea treatment effect was significantly higher than that of the sole cowpea treatment.

Percentage light interception in the sub plot factors also indicated that there were no differences among the varieties at 4 and 8 WAP. At 6 and 10 WAP samplings, treatment effect of Pan 53 and Obatanpa varieties were similar, and both effects were significantly higher than that of the Mamaba variety only.

Table 4.5 Percentage light interception (PAR) by maize as affected by cowpea intercrops

Treatments	Light Interception (%)			
	4WAP	6WAP	8WAP	10WAP
<u>Cowpea type</u>				
Erect cowpea	34.04	51.67	75.96	62.03 69.01
Spreading cowpea	36.50	55.13	74.13	61.23
No cowpea	31.61	48.05	56.88	
				7.64
LSD (0.05%)	NS	NS	9.91	13.78
C.V	21.34	18.16	16.60	
<u>Maize varieties</u>				63.46 65.13
Pan 53	34.22	53.56	72.08	60.66
Etubi	33.95	51.60	69.63	67.11
Mamaba	32.64	48.24	64.24	
Obatampa (OPV)	35.38	53.08	70.02	5.96
				11.11
LSD (0.05)	NS	4.51	NS	
C.V (%)	11.21	10.46	6.17	

4.6 Maize Stem Girth

Maize stem girth results shown in Table 4.6 was not significantly influenced by both factors on the 4 WAP and 6 WAP sampling, but on the 8 WAP and 10WAP, sole maize treatment (no cowpea) recorded significantly greater girth than the erect cowpea treatment effect. At the subplot level, the treatment effect of the Pan 53 variety was significantly higher than that of Mamaba variety on both 8 and 10 WAP samplings. The 10 WAP sampling also shows that the Obatanpa varietal effect was also greater than that of Mamaba. All other varietal differences were not significant.

Table 4.6 Girth of maize stem as affected by cowpea intercrops

Treatment	Maize stem girth (cm)			
	4WAP	6WAP	8WAP	10WAP
Cowpea type				
Erect cowpea	5.55 5.78	6.20 6.43	6.59 7.24	7.13 7.71
Spreading cowpea	5.56	6.64	7.83	8.29
No cowpea				
	NS	NS	1.06	1.14
LSD (0.05)	13.76	11.85	16.92	17.10
C.V (%)				
Maize varieties	5.95 5.55	6.88 6.43	7.43 7.22	7.96 7.66
Pan 53	5.49	6.08	6.97	7.42
Etubi	5.54	6.30	7.24	7.80
Mamaba				
Obatampa (OPV)	NS	NS	0.31	0.37
	10.06	7.93	5.16	5.67
LSD (0.05%)				
C.V				

4.7 Number of Green Maize Leaves

The results of number of green leaves on maize plants are shown in Table 4.7. On all sampling days the cowpea type did not significantly affect maize leaves (P>0.05). Among the varieties, Pan 53 recorded significantly greater number of green leaves than all other varieties on all sampling days. All other varietal effects were not different from one another

Table 4.7 Number of Green maize leaves as affected by cowpea intercrops

Treatments	Number of Green leaves			
	4WAP	6WAP	8WAP	10WAP

Cowpea type				
Erect cowpea	8.17 8.34	10.17 10.34	11.17 11.34	13.67 12.84
Spreading cowpea	8.09	10.09	11.09	12.59
No cowpea				
	NS	NS	NS	NS
LSD (0.05)	9.50	7.64	6.96	6.13
C.V (%)				
Maize varieties	8.90 7.93	10.90	11.89 10.94	13.39 12.44
Pan 53	8.02	9.94	11.02	12.52
Etubi	7.95	10.02	10.96	12.46
Mamaba		9.96		
Obatampa (OPV)	0.45		0.49	0.49
	7.09	0.49	5.19	4.58
LSD (0.05)		7.09		
C.V (%)				

4.8 Maize Chlorophyll Content (SPAD Value)

The result of maize chlorophyll content presented in Table 4.8. There were no significant differences among the means of the cowpea types at 4 WAP. However, at 6 and 10 WAP sampling, the effects of the no cowpea and the spreading cowpea treatments were similar, but were significantly higher than that of the erect cowpea treatment. At 8 WAP, the treatment effect of the no cowpea treatment was higher than that of only the erect cowpea treatment.

In the sub factor level, there were no significant differences among all the means ($P>0.05$) on all days of sampling except 4 WAP where Pan 53 recorded significantly ($P<0.05$) higher SPAD value than all other treatment effects.

Table 4.8 Chlorophyll content of maize as affected by cowpea intercrops

	Maize Chlorophyll content (SPAD unit)

Treatments	4WAP	6WAP	8WAP	10WAP
Cowpea type				
Erect cowpea	35.76	42.16	46.57 48.81	39.06 41.52
Spreading cowpea	37.73	44.62	52.44	42.27
No cowpea	38.03	45.37		
			4.90	2.06
LSD (0.05%)	NS	2.06	11.49	5.83
C.V	37.17	5.42		
Maize varieties			51.38 48.56	42.59 39.69
Pan 53	40.67	45.69	49.32	41.84
Etubi	35.73	42.79	47.83	39.68
Mamaba	37.65	44.94		
Obatampa (OPV)	34.65	42.78	NS	NS
			8.87	8.69
LSD (0.05%)	2.95	NS		
C.V	9.47	8.08		

4.9 Grain Yield, Stover Weight, Shelling Percentage, Hundred Grain Weight And Harvest Index Of Maize.

4.9.1 Maize Grain Yield

Table 4.9 shows grain yield of maize, stover weight, shelling percentage and hundred grain yield weight. Grain yield of sole maize (No cowpea) plot produced significantly greater grain yield than maize intercropped with erect cowpea plots. Maize yield in the intercropped treatments were similar. In the subplot treatments, Pan 53 produced significantly greater yield than all the other varieties ($P<0.05$). Also Obatanpa produced significantly higher yield than Etubi and Mamaba varieties ($P<0.05$). But there was a no difference among Etubi and Mamaba grain yields ($P>0.05$).

4.9.2 Stover Yield of Maize

Maize stover yield as shown in Table 4.9 was not significantly different among the cowpea types. However, among the sub treatments Pan 53 again recorded greater stover yield than that of Mamaba only. Again, Mamaba variety recorded significantly lower ($P<0.05$) stover yield than those of Etubi and Obatampa varieties.

4.9.3 Shelling Percentage of Maize

The results of both the main plot factors and the sub plot factors shown in Table 4.9 recorded no significant ($P>0.05$) differences among the various combinations.

4.9.4 One Hundred Seed Weight of Maize

Hundred seed weight of maize among main plot treatments were not significant. However, in the sub plot treatment, all the four means were significantly different from one another. Pan 53 recorded highest, followed by Obatanpa, Etubi and Mamaba. (Table 4.9).

4.9.5 Harvest Index of Maize

Results of Maize harvest index were greatest in the no cowpea treatment, but this was significantly higher than that of the spreading cowpea treatment only. The two cowpea intercropped plots did not differ in harvest index.

Among the varieties, Pan 53 recorded significantly higher harvest index than the three other varieties ($P<0.05$), all of which did not differ from one another in their harvest indices.

Table 4.9 Grain yield, Stover weight, shelling percentage, 100 grain weight and Harvest Index of maize as affected by cowpea intercrops

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Shelling %	100 grain Weight(g)	Harvest Index (%)

<u>Cowpea type</u>					
Erect cowpea	2425.00	4876.10	85.59	23.81	31.64 39.46
Spreading cowpea	2808.30	4201.70	79.90	24.13	45.71
No cowpea	3633.30	4126.70	78.92	24.93	
					7.84
LSD (0.05%)	994.92	NS	NS	NS	23.28
C.V	38.91	32.82	17.37	12.93	
<u>Maize varieties</u>					47.70 32.74
Pan 53	4622.20	5060.60	84.83	27.75	36.96
Etubi	2133.30	4445.50	83.18	23.08	38.36
Mamaba	2100.00	3366.30	79.68	20.67	
Obatampa (OPV)	2966.70	4733.60	79.18	25.67	6.61
					20.26
LSD (0.05)	671.89	924.95	NS	1.69	
C.V (%)	27.14	25.09	14.40	8.29	

4.10 Volumetric Water Content (VWC)

Moisture level among the cowpea growth type intercrops at 4 WAP and 10 WAP did not show any significant difference (P>0.05). However, in the 6 and 8 WAP, sole maize or No cowpea recorded significantly lower moisture content as compared to the intercropped plots (P<0.05)

Hybrid varieties did not have significant influence on the soil moisture on all sampling days (Table 4.10).

Table 4.10 Volumetric Water Content (VWC) of soil as affected by cowpea intercrops

Treatments	Volumetric Water Content (%)			
	4WAP	6WAP	8WAP	10WAP

<u>Cowpea type</u>				
Erect cowpea	21.62	15.98	19.98	23.63
Spreading cowpea	22.15	15.93	19.93	24.15
No cowpea	21.71	14.39	18.39	23.71
LSD (0.05)	NS	1.43	1.43	NS
C.V (%)	13.89	10.72	8.52	12.72
<u>Maize varieties</u>				
Pan 53	21.04	15.19	19.19	23.04
Etubi	22.37	16.13	20.13	24.37
Mamaba	22.30	15.31	19.31	24.29
Obatampa (OPV)	21.62	15.11	19.11	23.62
LSD (0.05)	NS	NS	NS	NS
C.V (%)	9.45	8.46	6.72	8.66

4.11 Percentage Root Lodging

Result of root lodging presented in Table 4.11 showed that lodging was significantly higher ($P<0.05$) with sole maize as compared to intercropped maize. But there were no significant differences among the two groups of intercrops ($P>0.05$).

Among varieties, maize root lodging was greatest in Mamaba plot, and this was significantly higher than in Etubi and Obatanpa plots only. Treatment effect of Pan 53 was also significantly higher than Etubi and Obatanpa plots. The difference in the treatment effects of Etubi and Obatampa were not significant.

4.12 Days To 50% Tassel Initiation

Days to 50% tasselling in maize was not significantly affected by cowpea type and maize hybrid varieties (Table 4.11).

Table 4.11 Percentage Lodging and Days to 50% Tasselling

Treatments	Lodging (%)	Days to 50% Tasselling
Cowpea type		
Erect cowpea	3.38 3.31	57.03 56.63
Spreading cowpea	5.00	56.50
No cowpea		
	1.21	NS
LSD (0.05)	35.86	3.52
C.V (%)		
Maize varieties	4.62 2.75	57.00 56.58
Pan 53	5.00	57.00
Etubi	3.42	56.33
Mamaba		
Obatampa (OPV)	0.72	NS
	21.99	3.48
LSD (0.05)		
C.V (%)		

4.13 Weed Score and Dry Matter Yield

Results on weed score and dry matter yield are shown in Table 4.12. The result showed that weed infestation in the first weeding was not significantly affected by all treatments. At the second weed score, the no cowpea treatment effect was significantly higher than the intercropped treatments. The intercropped treatment effects were not different from one another. Maize hybrid type did not significantly affect the second weed score.

With the sub plot treatments, there were no significant pairwise differences among the means of the first and the second score ($P>0.05$). Weed dry matter, however, was lower in Pan 53 and Obatanpa plots compared to Etubi and Mamaba plots ($P<0.05$).

Table 4.12 Weed score and dry matter yield as affected by cowpea intercrops.

Treatments	Score 1 (m^2)	Score 2 (m^2)	Weed dry matter (kg/ha.)

Cowpea type			
Erect cowpea	1.94 1.69	1.43 1.31	993.70
Spreading cowpea	1.94	1.75	2406.30
No cowpea			2375.00
	NS	0.30	
LSD (0.05)	20	22.91	582.99
C.V (%)			34.99
Maize varieties	1.83 1.67	1.42 1.67	
Pan 53	1.72	1.58	1500.00
Etubi	2.00	1.33	2166.70
Mamaba			2200.00
Obatampa (OPV)	NS	NS	1833.30
	32.18	35.43	
LSD (0.05)			634.08
C.V (%)			39.32

4.14 Grain yield of Maize and Cowpea and Land Equivalent Ratio - On-farm

The results of these parameters are presented in Table 4.13. Among the sole maize treatments, Pan 53 produced the greatest grain yield, and this was significantly higher than all the varietal effects. Grain yield of the other three sole maize crops were not significantly different from one another.

Maize grain yield in all the intercrops were lower than in the sole crops, irrespective of the cowpea type used. Not with-standing, there was a greater reduction in maize yield when erect cowpea was the intercrop, compared to spreading cowpea. Among the intercrop, whether with erect or spreading cowpea, Pan 53 yield was the greatest whilst the Mamaba variety produced the lowest grain in both intercrop cases.

Grain yield of the sole cowpea was significantly higher than in the intercrops, whether erect or spreading type. Indeed, intercropping reduced grain yield of cowpea between 70% and 100%.

The Land Equivalent Ratio for all intercrops was greater than one. The greatest, 1.57 was recorded in the spreading cowpea and Mamaba variety, and this was significantly higher than those of erect cowpea and Pan 53 and erect cowpea and Obatanpa variety.

Table 4.13 Maize grain yield, cowpea grain yield and LER as affected by intercropping systems.

Treatment	Maize Grain Yield (kg/ha.)	Cowpea Grain Yield (kg/ha.)	LER
Sole Pan 53	3235.90	-	-
Sole Etubi	2274.50	-	-
Sole Mamaba	2026.60	-	-
Sole Obatanpa	2403.60	-	-
E.CP/Pan 53	2814.80	211.50	1.31 1.40
E.CP/Etubi	2046.90	237.75	1.43 1.35
E.CP/Mamaba	1660.40	296.25	1.41 1.51
E.CP/Obatanpa	2006.80	248.00	1.57
S.CP/Pan 53	2863.40	210.00	1.55
S.CP/Etubi	2148.10	225.25	-
S.CP/Mamaba	1834.40	262.50	-
S.CP/Obatanpa	2170.20	258.50	0.20
Sole Erect C.P	-	481.48	11.23
Sole Spreading C.P	-	398.73	
	420.74		
LSD (0.05)	12.77	48.48	
C.V (%)		39.87	

4.15 Economic Returns – On-Farm 4.15.1 Variable Cost, Net Benefit and Benefit Cost Ratio of Maize and Cowpea As

Affected By the Intercropping Systems at the On-Farm Level

4.15.1.1 Variable Cost of Production

Generally the results showed that cost of production was higher with the cowpea intercrops with Pan 53 with a value of GHC1262.50 per hectare as compared to the local hybrids and the open pollinated variety, Obatanpa. Cowpea intercropped with Obatanpa recorded lowest cost of production with an amount of GHC1049.30 (Table 4.14). Partial budgeting and the prices of inputs and other cost of farm operations during the experimental period are presented in the appendices.

4.15.1.2 Net Benefit (Net Returns)

Generally, all the cowpea intercrops/maize intercrops showed higher total net returns as compared to sole maize. Spreading cowpea intercropped with Pan 53 variety recorded the highest value of GHC1954.56. Sole Mamaba variety recorded the lowest value of GHC 911.94.

4.15.1.3 Benefit Cost Ratio (BCR)

Except Pan 53 variety, all the results of BCR of cowpea/maize intercrops showed a higher ratio as compare to the result of their respective soles (Table 4.14). However, differences between the sole Pan 53 and its intercrops were not significant since all were above a ratio of 1.5

Table 4.14 Variable cost and net benefit of maize and cowpea as affected by the intercropping systems at the on-farm level

Treatment	Maize Grain yield Kg/ha.	Cowpea Grain yield Kg/ha	Gross return of maize (GHC) *(100kg/bag=GHC90.00)	Gross return Of cowpea(GHC) **(1kg=GHC3.00) **107 kg= 1bag	Total Gross returns (GHC)	Total Variable cost of production (GHC)	Net returns (GHC)	Benefit Cost Ratio (BCR)
Sole Pan 53	3235.90	-	2912.31	-	2912.31	1056.00	1856.31	1.76 1.24
Sole Etubi	2274.50	-	2047.05	-	2047.05	912.00	1135.05	1.00 1.54
Sole Mamaba	2026.60	-	1823.94	-	1823.94	912.00	911.94	1.51 1.28
Sole Obatanpa	2403.60	-	2163.24	-	2163.24	852.80	1310.44	1.13 1.41
E.CP/Pan 53	2814.80	211.50	2533.32	634.5	3167.82	1262.50	1905.32	1.56 1.35
E.CP/Etubi	2046.90	237.75	1842.21	713.25	2555.46	1118.50	1436.96	1.20 1.60
E.CP/Mamaba	1660.40	296.25	1494.36	888.75	2383.11	1118.50	1264.61	5.99
E.CP/Obatanpa	2006.80	248.00	1806.12	744.00	2550.12	1059.30	1490.82	5.08
S.CP/Pan 53	2863.40	210.00	2577.06	630.00	3207.06	1252.50	1954.56	
S.CP/Etubi	2148.10	225.25	1933.29	675.75	2609.04	1108.50	1500.54	
S.CP/Mamaba	1834.40	262.50	1650.96	787.50	2438.46	1108.50	1329.96	
S.CP/Obatanpa	2170.20	258.50	1953.18	775.50	2728.68	1049.30	1679.38	
Sole Erect CP	-	481.48	-	1444.44	1444.44	206.5	1237.94	
Sole S.CP	-	398.73	-	1196.19	1196.19	196.5	999.69	

Total Gross return = Gross returns of maize + cowpea

Total variable cost of production = Land preparation+ inputs + cost of labour for farm operations

Net returns = Total Gross returns – Total variable cost of production Benefit

cost ratio = Net returns / Total variable cost of production.

CHAPTER FIVE DISCUSSION

5.1 Soil Nutrient Analysis 5.1.1 Soil pH, OC %, total N, available P and exchangeable K as Affected by

Cowpea Intercrops

Soil fertility characteristics of lowlands within the Guinea Savannah are 4.6, 6.10, 0.65, 1.5 and 0.22 for pH, OC, total N, available P and exchangeble K and these showed how the soil at project site was very low in % OC and total N (Buri *et al*., 2004). The inability of farmers to buy adequate amounts of mineral fertilizers to improve their crop yields is therefore a major factor affecting food security. Use of locally available materials for soil improvement is an option that must be fully exploited (Buri *et al*., 2004).

Trend in the soil analysis indicated a slightly increased pH, OC and total N at harvest as compared to initial soil analysis. Also, there was significant increase in OC and total N in the intercropped main plots as compared to the sole maize. This was probably because intercrop combinations included crop associations of components densities higher in sole maize and cowpea in the same space and this may have returned larger biomass and hence residue in the form of senesced leaves and roots to the soil. This was also observed by Giller *et al*. (1997) and Midmore (1993). This result augments some of the evidence about the possibility of maintaining soil productivity through the inclusion of cowpea in intercropping systems. Redy *et al*. (1992) reported that intercropping affects fertility maintenance through nitrogen fixation and differential uptake of nutrients. Charles-marie (1992) also reported that some legumes provide free supply of about 15-20 kg ha $^{-1}$ per month during growing season due to nitrogen fixation. The trend observed for soil OC and N were different from that of P and K nutrient elements. The soil K dynamics after harvest suggested that the nutrient was more exploited by intercrops than by the sole maize.

5.2 Effect of Cowpea Intercropping Systems on the Vegetative Growth of Maize

5.2.1 Plant Height

Maize plant height was affected significantly by the type of cultivar and competition from the intercrop. The sole maize was superior to the intercropped maize at 8 WAP and 10 WAP. This suggested that competition was not severe between the 4 WAP and 6 WAP, presumably due to the smaller size of the cowpea plants since they were planted two weeks after the maize. The result also suggested that the level of competition was greater in the later periods because of the need to mobilize resources for accelerated growth. Any advantage in biomass production would have resulted in the correct orientation of the leaves for maximum light interception as reported by Alhassan (2000).

Pan 53 and Obatampa recorded no significant differences in height and this trend reflected in the number of leaves, stem girth and LAI. These made them more efficient and effective in competing and accessing growth factors including nutrient, water, sun light, air and also suppressed weeds that would have competed with them. This was also reported by Du-Plessis (2003). It could also be linked to genetic characteristics. These also translated into bigger and heavier cobs with well filled grain yield as also reported earlier by Buah *et al*. (2009).

5.2.2 Leaf Area Index (LAI)

Sole maize significantly recorded higher LAI as compared to the maize intercropped with both cowpea types as plant growth of the sole maize was higher as a result of less competition. Earlier result on sorghum which is widely cultivated under the same conditions in the North, however, showed that the intercropped sorghum produced greater

LAI than the sole crop (Alhassan, 2000). LAI values of all treatments declined after 8 WAP probably due to less partitioning of dry matter into leaf production in favour of the principal physiological activities this stage that demanded dry matter accumulation and storage. Alhassan (2000) and Kombiok (2004) reported similar observation, and this might have been as a result senescence.

Pan 53 recorded significant higher LAI as compared to the Etubi, Mamaba and Obatanpa varieties at 8 and 10 WAP. This variation is a characteristic feature of Pan 53 hybrid which exhibit different growth rates due to their abilities to produce extensive roots to compete for growth. Similar observation was earlier made by Mawusi (2013).

5.2.3 Light Interception (PAR)

Results of percentage radiant energy interception by maize showed that there was an increase in light interception from 4 to 8 WAP after which it declined. The gradual decline of radiant energy interception has also been reported by Kombiok (2004). Keating and Carbery (1993) and Alhassan (2000) reported that sole crops planted at higher densities achieved greater LAI and captured greater solar radiation in their studies. Light interception by the hybrids showed that Mamaba recorded the least light interception as compared others. This suggested that Mamaba may be inefficient in competing for light, apparently because Mamaba plants were shorter than the others beyond 6 WAP. Alhassan (2000), reported a similar trend in PAR interception and suggested that significant differences in biomass production was not attributable to differences in light but probably due to competition for light and below ground resources. General decrease in light interception by the 10 WAP may be attributed to a reduction in mean leaf biomass (LAI) as a result of senescence.

5.3 Effect of Cowpea Intercropping Systems on Harvest Crop Yield

5.3.1 Maize Grain Yield and Yield Components

From the result of grain yield of the study, sole maize produced significantly greater grain yield compared to their intercrops. Intercropping significantly reduced maize grain yield by 22.7% and 33.25% in the erect and spreading cowpea intercrops respectively. Cowpea grain yield also declined due to intercrop. The reduced grain yields obtained in the intercrops compared to their monocultures were due mostly to competition for resources such as soil nutrients, moisture and light. Similar observations were made by Drisah (2006) and Kombiok (2004) who reported a significant reduction in maize grain yield intercropped with mucuna and cowpea respectively. Several work done on maize/cowpea mixtures showed that, even though there are usual yield reductions in the component crops when compared with their sole or pure stands, economically, the losses are compensated for by the yields of the component crops.

Pan 53 out yielded all the other maize varieties including Obatanpa. This outstanding performance confirms similar results observed by Akande and Lamidi (2006) and AlHassan and Jatoe (2002). Again the result confirms those of Masara N‟Arziki (2011) where 5000 kg/ha of yield for the PANNAR varieties were obtained. In this study, Obatanpa recorded greater yield than Etubi and Mamaba varieties which was different from the result obtained by Kande and Lamidi (2006) who reported that local hybrids were superior to Obatanpa in terms of yield. The result obtained with Obatanpa suggested that the variety can withstand competition with cowpea intercrops better than the two hybrids with a reason that the variety is adopted to the tropical conditions. Obatanpa was released as a medium-maturing open-pollinated QPM variety in 1992, but still the predominant variety and has even increased in popularity over the years, while the newer varieties do not seem to have taken off (Sallah *et al*., 2003). This is the likely reason newer varieties are not able to replace Obatanpa.

Grain yield obtained from on-farm experiments also indicated significant higher yield of PANNAR variety in the pure stand similar to that of the on-station. Though there were similar yield reductions in grain yield of both maize and cowpea in their intercrop plots, all their Land Equivalent Ratio (LER) were above unity and clearly showed that there was an advantage in intercropping. LER is an index of intercropping productivity which has been found to be the same as the fractions of the yields relative to their sole (Francis, 1986).

LER for intercropping has three possible outcomes, i.e. yield advantage (LER>1), yield disadvantage (LER<1) and the intermediate result (LER=1). With this result, it means land resource use efficiency was better guaranteed by intercropping the respective varieties of cowpea and maize used in the study.

Again, Obatanpa had higher LER of 1.5 and 1.3 with spreading and erect cowpea, respectively.

Pan 53 recorded greater stover yield over the other varieties. This could be helpful to crop farmers who keep livestock, who can use the maize stover as animal feed.

5.4 Weed Score and Dry Matter Yield

The result showed that weed infestation in the first weeding (3 WAP) was not significant in both sole and intercropped maize plots, yet weed infestation in the spreading cowpea plots were lower than in both the sole maize and maize /erect cowpea intercrop. Weed score in the second occasion however, showed not only reduction among all intercrop plots, but also the spreading cowpea/maize intercrop had significantly reduced weed population greater than the sole maize field. However, weed dry matter in the spreading cowpea intercrop was greater than the erect cowpea intercrops at final weed harvest. This was not surprising as harvesting of final weed samples were done after maturity of maize, and by this period the biomass of the spreading cowpea which matured earlier and wilted before the erect cowpea might have contributed some nutrients to the weeds which promoted the growth. One of the basic reasons why farmers intercrop is weed control.

Several reporters have reported reduction of weed infestations as a result of intercropping (Kombiok, 2004, Wanic *et al*., 2004, Poggio, 2005)

5.5 Economic Returns as Affected by the Intercropping Systems at the On-Farm Level

5.5.1 Cost of Production

The general variable cost of production for the study period was due to the increase in farm inputs and farm operations as well as general increase in prices of goods and services in Ghana. Cowpea/maize intercropped plots recorded higher cost of production to the sole plots with intercropping systems with Pan 53 recording the highest cost of production while Obatanpa/cowpea intercropped recorded significantly lower cost of production. This was not surprising as the cost of Pan 53 seed maize was significantly higher than the other varieties as the seed is always imported (Al-Hassan and Jatoe, 2002; Kanungwe, 2009). Low cost of production with Obatanpa was attributed to the low cost of seed as land preparation, labour for farm operations and inputs used were all fixed price. Cost of cowpea seed, cost of insecticide for insect pest, cost of labour incurred in spraying the insecticide, harvesting and threshing are found to be responsible for the highest cost of production for these intercrop treatments as compared to pure stand.

However, chemical fertilizer was the highest variable cost among all.

5.5.2 Net Benefit of Maize and Cowpea

The greatest total net returns of maize and cowpea were from the intercropped plots with Pan 53 intercropped with spreading cowpea recorded highest net return. This could be attributed to the higher yield obtained from the variety.

5.5.3 Benefit Cost Ratio (BCR)

All the results of BCR of cowpea/maize intercrops showed a higher ratio as compare to the result of their respective soles. However, differences between the sole Pan 53 and its intercrops were not significant since all were above a ratio of 1.5. This gave indications that there is an advantage in intercropping over that of sole cropping. With the Pannar variety it showed that either sole or intercrop you will still achieve higher BCR.

Sole Cowpea on the other hand recorded higher BCR values as compared to intercropping with maize.

CHAPTER SIX CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Based on the findings of the study on crop performance as well as crop environmental parameters obtained, the following conclusions were drawn:

(i) Although maize in pure stands produced higher grain yield than their intercrops, the LERs of the intercrops at on-farm for all the treatments were more than unity (>1) and that suggested that productivity was higher in the intercropping systems than the sole cropping system. Also, the BCR of all the intercrops showed good returns.

(ii) All the hybrid maize can do well with the mixture of the two growth types of cowpea. Obatanpa as an OPV is adapted to the growing conditions in the lowland tropics and could withstand the competitive effects of intercropping to give good returns. With the Pannar variety both the sole and the mixture showed no significant differences.

(iii) Where the weeds situation is severe, it is advisable to use the spreading type of cowpea as an intercrop as this can serve as an underground storey to effectively smoother weeds.

6.2 Recommendations and Future Research Direction

The following recommendations are made:

1. Soils in Northern Ghana are generally low in nitrogen and in order to raise the N level for maize production and also to minimise the use of in-organic fertilizers, intercropping with cowpea is appropriate as it would be able to fix substantial quantities of N.
2. Obatampa can be adopted as a good material for intercropping provided farmers will continue to buy fresh seed from a certified source every season since that could guarantee higher yield than farmer-saved seed.
3. Large scale farmers with the preference of sole cropping should depend largely on the use of Pan 53 while the small scale farmers can concentrate much on intercropping with the appropriate advice from their Extension Agents
4. Future cropping system research in the region should focus on evaluation of long term effects of different cropping systems on soil chemical and physical properties and crop yields, the effects of different legume intercrops on the growth and yield

of hybrids and the influence of time of the intercropping systems on soil and water conservation and on crop yield.

REFERENCES

1. Abalu, G.O.I (1977) Notes on mixed cropping under indigenous conditions in Nigeria. Journal of Development studies 13:212-211

2. Adu-Gyamfi, J.J., F.A. Myaka, W.D. Sakala, R. Odgaard, J.M. Vesterager, and H Hogh-Jensen. (2007). Biological Nitrogen Fixation and Nitrogen and Phosphorus Budgets in Farmer-Managed Intercrops of Maize-Pigeonpea in Semi-arid Southern and Eastern Africa. Plant and Soil. 295(1-2): 127-136.

3. Akande, S. R. and Lamidi G. O. (2006). Performance of Quality Protein Maize Varieties and Disease Reaction in the Derived Savanna Agro- Ecology of South-West Nigeria.Afi. J. Biotechnol., 5:1744-1748.

4. Akanda, M. E. and Quayyam M. A. (1982). Effect of intercropping soybean, cowpea, mungbean, blackgram and groundnut with maize. Bangladesh Agric Res. 7 (2): 66-69

5. Alene, A., and Mwalughali J. (2012). "The Effectiveness of Crop Improvement Programs in Sub-Saharan Africa from the Perspectives of Varietal Output and Adoption:
The Case of Cassava, Cowpea, Maize, and Soybean." Draft Technical Report for Measuring and Assessing the Impacts of the Diffusion of Improved Crop Varieties in Africa (DIVA) Project, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

6. Alhassan, A. Y. (2000). Effect of seedbed type and different intercrop densities of soya bean (Glycinemax) and pigeonpea (Cajanus cajan) on the performance of sorghum

(*Sorghumbicolor*) in the Guinea Savannah zone of Northern Ghana. Ph.D. Thesis, University of London (Imperial College at Wye)

7. Al-Hassan R. and Jatoe J.B.D (2002). Adaptation and impact of improved cereal Varieties in Ghana. Paper prepared for the workshop on the green revolution in Asia and its transferability to Africa. Organised by Foundation for Advanced Studies in

International Development (FASID), from 8th to 10th December, 2002, in Tokyo, Japan

8. Almekinders, C.**,** (2001)**.** Management of Crop Genetic Diversity at Community Level. GTZ, Eschborn. 269-275

9. Altieri, M.A., (1995). Agroecology: the science of sustainable agriculture, second edition. Westview Press, USA.

10. Amanullah M. M, Alagesan A, Vaiyapui K, Sathyamoorthi K and Pazhanivelan S (2006). Effect of intercropping and organic manures on weed control and performance of cassava (*Manihot esculenta* Cranz). Journal of Agron 5(4):589-595.

11. Andrews, D.J., and Kassam A.H. (1976).The importance of multiple cropping in increasing world food supplies. In *Multiple Cropping.* Special Publication No. 27. Madison, Wisconsin: American Society of Agronomy.

12. Anem, M., Doa, M. and Malaysia, J., (2001). Anim Agriculture

Technology Animagro**.** Monday September, 5th 2011

13. Anil, L. P. Park, R.N Phpps and Miller, F.A (1998). Temperate intercropping of cereals for forage; A review of the potential for growth and utilization with particular references to the UK. Grass. Forage Science 53:301-317.

14. Augustine B (2003). Urban areas-source of pesticide contamination of surface water? p. 166-169. In: Balder H, Strauch KH, Backhaus GF (Eds.). Second International

Symposium on Plant Health in Urban Horticulture, Berlin, Germany

15. Banik P., Midya A., Sarkar, B. K and Ghose SS (2006). Wheat and Chickpea intercropping systems in additives experiments. Advantages and weed smothering. Europ T. Agron 24: 325-332

16. Bastiaans, L., Kropff, M.J., Goudriaan, J., Van Laar, H.H., (2000). Design of weed management systems with a reduced reliance on herbicides poses new challenges and prerequisites for modelling crop-weed interactions. Field Crops Research 67, 161– 179.

17. Beets, W.C. (1990). Raising and Sustaining Productivity of Smallholder Farming Systems in the Tropics. Alkmaar, Holland: AgBé Publishing.

18. Boukar, O., Massawe F., Muranaka, S., Franko J., Maziya-Dixon, B., and C. Fatokan (2010). Evaluation of cowpea germplasm lines for minerals and protein content in grains.

19. Brown W.L. and Darrah L.L. (1985). Origion, Adoptation and Types of Corn Cooperatives Extension Service.Iowa State University. Ames, Iowa 50011.

20. Buah S. S. J., Abatania L. N. and Aflakpui G. K. (2009). Quality Protein Maize

Response to Nitrogen Rate and Plant Density in the Savanna Zone of Ghana. West Africa Journal of Applied Ecology, vol. 16: 9-11.

21. Buri, M. M., Issaka, R. N. T. Wakatsuki and E. Otoo (2004) Soil organic amendments and mineral fertilizers: Options for sustainable lowland rice production in the Forest agro-ecology of Ghana. Agriculture and Food Science Journal of Ghana. Vol., 3: 237-248

22. Carlson J.D. (2008). Intercropping with Maize in Sub-arid Regions. Community Planning and Analysis Technical Brief, April 16 2008.

23. Carruthers K, Fe, Q,, Cloutier D, and Smith D. L. (1998). Intercropping corn with soybean, lupin and forages: Weed control by intercrops combined with inter row cultivation. Europ J Agron 8:225-238.

24. Carruthers K, Prithiviraj B, Fe Q, Cloutier D, Martin RC, and Smith D. L. (2000) Intercropping corn with soybean, lupin and forages: yield component responses. Eur J Agron 12:103-115.

25. Cenpukde U. and Fukai S. (1992)a. Cassava/legume intercropping with contrasting cassava cultivars. 1. Competition between components crops under three intercropping conditions. Field Crops Res. 29:113-133.

26. Cenpukdee U, and Fukai S (1992)b. Cassava/legume intercropping with contrasting cassava cultivars. 2. Selection criteria for crops. Field Crops Res 29:135-149.

27. Chang, J.F., and Shibles R.M. (1985). An analysis of competition between intercropped cowpea and maize. The effect of fertilizer and plant population. Field Crops Research 12: 145-152.

28. Charles-Marie, M. (1992). The Tropical Vegetable Garden: Principles for Improvement and Increased Production and Application to the Main Vegetable types. Macmillan Press. Pp514

29. CORAF/WECARD Cowpea report (2011). WWW.coraf.org

30. Dalal, R.C. (1974). Effects of intercropping maize with pigeon pea on grain yield and nutrient uptake. Experimental Agriculture 10: 219-224.

31. Danso, S.K., Hardarson G. and Fried M. (1987). Nitrogen fixation in faber beans as affected by plant population density in sole or intercropped systems with barley. Soil Biology and Biochemistry, 19: 411-415.

32. Doss, C. R. (2006). Analysing Technology Adoptation Using Microstudies: Limitations, Challenges and Opportunities for Improvement. Agricultural Economics 35:207-219.

33. Drisah, Y.J. (2006). Time of planting mucuna and canavalia as an intercrop and its effects on yield of maize. BSc. Dissertation, Faculty of Agric., UDS, Tamale. Pp 2-34 34. Du-Plessis J., (2003). Maize production. Agricultural Information Service, DepartmentAgriculture,Pretoria,SouthAfrica.http//:Fastonline.org/CD3WD40/LSTOCK/0 01/SAInfoPaks/docs/ maize production.

35. Eskandari, H., (2012). Intercropping of maize (*Zea mays*) with cowpea (*Vigna sinensis*) and mungbean (*Vigna radiata*): effect of complementarity of intercrop components on resource consumption, dry matter production and legumes forage quality. Journal of Basic and Applied Scientific Research, 2: 355-360.

36. Eskandari, H., A. Ghanbari-Bonjar, M. Galavai and M. Salari, (2009). Forage quality of cow pea (*Vigna sinensis*) intercropped with corn (*Zea mays*) as affected by nutrient uptake and light interception. Notulae Botanicae Horti Agrobotanici ClujNapoca, 37: 171-174.

37. Eskandari, H, and Ghanbari, A. (2009). Intercropping of maize and cowpea as whole-crop forage: effect of different planting pattern on total dry matter production and maize forage quality. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 37(2):152-155.

38. Ezello, O.O. (1996): Characteristics effect of intercropping arable crops in the tropics. New York.

39. Fortin, M.C.; Pierce, F.J. (1996) Leaf azimuth in strip-intercropped corn. Agronomy Journal, Madison Vol. 88:6-9

40. Francis C.A (1986) Introduction. Distribution and importance of multiple cropping. In New York, N.Y. USA.pp1-19

41. Francis, C.A., (1989). Biolgical efficiencies in multiple cropping systems. Advance in Agronomy, 42: 1-42.

42. Francis, C.A., Flor, C.A., and Temple, S.P. (1976). Adapting varieties for intercropping systems in the tropics. In: Papandick, R.I.; Sanchez, P.A.; Triplett, G.B. (Eds.). Multiple cropping. Madison: American Society of Agronomy. p.235-253.

43. Fujita, K., Ofosu, K.G. and Ogata, S. (1992). Biological nitrogen fixation in mixed legume-cereal cropping system. Plant and Soil, 144: 155-175.

44. Fukai S. and Trenbath B.R (1993). Processes determining intercrop productivity and yields of component crops. Field Crops Res 34:247-271.

45. Ghanbari-Bonjar A. (2000). Intercropped wheat and bean as a low-input forage. PhD thesis. Wye College. Univ. London.

46. Gharinch M. H, and Moosavi S. A. (2010). Effects of intercropping (canola-faba bean) on density and diversity of weeds. Notulae Scientia Biologicae 2(4):109-112.

47. Giller, K.E., McDonagh J.F. and Cadisch G. (1994). Can biological nitrogen fixation sustain agriculture in the tropics? Njas- Wageningen Jour. Life Sci. V.48,115-122

48. Giller, K.E., Cadisch,G., Ehaliotis C., Adams, E., Sakala, W.D and Mafongo,P.L. (1997). Building soil Nitrogen capital in Africa. Replenishing soil fertility in Africa society of Agronomy and soil science society of America. SSSA Special publication no. 51

49. Giller, K. E., (2001). Nitrogen fixation in tropical cropping systems. 2nd edition, Cabi Series, CABI Publishing series.Web. http://books.google.fr/books

50. Girjesh, G.K. and V.C. Patil, (1991). Weed management studies in groundnut and sunflower intercropping system. Journal of Oilseeds Research, 8: 7-13.

51. IFPRI. (2013). Patterns of Adoption of Improved Maize Technology in Ghana.
Working paper 36/July 2013

52. Innis, D.Q. (1997). Intercropping and the Scientific Basis of Traditional Agriculture. London: Intermediate Technology Publications.

53. Isenmilla, A.E. Babalola, O., and Obigbesan, G.O. (1981). Varietal influence of intercropped cowpea on the growth, yield and water relations of maize. Plant and soil 62
(1), 153-156.

Ishiyaku, M.F., Higgins T.J, Umar M.L., Misari S.M., Mignouna H.j., Nang Ayo F., Stein, J., Murdock, L.M., Obokoh, M. and Huesing J.E (2010). Field evaluation of some transgenic maruca resistance Bt cowpea for Agronomic traits under confinement in Zaria, Nigeria. http://legumelab.msu.edu/uploads/files/WorldCowpeaConference.

54. Jension E. E., Ambus N., Bellostas N., (2006). Intercropping of cereals and Grain legumes for increased production, weed control, improved product quality and prevention of N-losses in European organic farming systems. Proceedings of the European Joint Organic Congress. Odense, Denmark, P. 180-182.

55. Kadziuliene Z, Sarunaite L, Dereikyte I, Maiksteniene S, Arlauskiene A, Masilionyte L, Cenuleviciene R, and Zekaite V (2009). Qualitative effects of pea and spring cereals intercrop in the organic farming systems. Agron Res 7(2):606-611.

56. Kanungwe M. B. (2009). Anticipated Demand and Challenges to plant Breeding and related Technologies into the future. Presented at the 2nd World Seed Conference-

Rome 8th to 9th September 2009.

57. Keating, B.A. and Carberry, P. S. (1993). Resource capture and use in intercropping: Solar radiation. Field Crop Research, 34,273-301.

58. Kimbrell, A. (1998). „Why Biotechnology and High- Tech Agriculture Cannot Feed the World. *The Ecologist*. 28, 5:294-298.

59. Kombiok, J.M (2004). Tillage and cropping systems effects on soil moisture, nitrogen fixation and yield of cowpea intercropped with maize in Northern Ghana. Ghana journal of Agrc. Sci. 34, 108-109

60. Kropff, M. (1993). General introduction, p. 1-8. In: Kropff M, Vanlaa H (Eds.). Modelling crop-weed interactions. CAB International, Walling ford, UK.

61. Kuchinda, N. C. (2003). On-farm evaluation of improved maize varieties intercropped with some legumes in the control of Striga in the Northern Guinea savanna of Nigeria. Crop. Prot., vol. 22: 533-538.

62. Kumwenda, J.D.T., Kabambe V.H.K. and Sakala W.D.M. (1993). Maize-soybean and maize-bean intercropping experiments. In Maize Agronomy Annual Report for 1992/9*3*. Lilongwe, Malawi: Chitedze Agricultural Research Station.

63. Langyintuo, A., Larry, M., Lowenberg-DeBoer, J.; and Ntoukam, G. (2000). The Market Value of Cowpea Characteristics in Cameroon and Ghana. Paper presented at the World Cowpea Conference III. IITA-Ibadan. Nigeria.

64. Lantinga, E.A., Nassiri, M., Kropff, M.J., (1999). Modelling and measuring vertical light absorption within grass–clover mixtures. Agricultural and Forest Meteorology 96, 71–83.

65. Liebman, M. and Davis, A.S. (2000). Integration of soil, crop and weed management in low-input farming systems. Weed Res., v. 40, n. 1, p. 27-47,

66. Liebman M. and Dyck E (1993). Crop rotation and intercropping strategies for weed management. J Appl Ecol 3:92-122.

67. Lithourgidis A.S, Dordas C.A, Damalas C.A, Vlachostergious D.N (2011). Annual Intercrops: An Alternative Pathway for Sustainable Agriculture Annual Intercrops

68. Mahapatra, S.C., (2011). Study of Grass-legume intercropping system in terms of competition indices and monetary advantage index under acid lateritic soil ofIndia. America journal of experimental Agriculture, 1 (1) : 1-6

69. Masara, (2009). Report on the launch of Masara N‟Arziki Farmers Association (MAFA) in Tamale. 24th November, 2009.

70. Masara, (2011). Maize Production guide for Masara N‟Arziki Extension Agents. P. 29-31

71. Mashingaizde A. B, Nyakanda, C, Chivinge O. A., Washaireni A. M, and Dube K. W. (2000). Influence of a maize pumpkin live much on weed dynamics and maize yield. African Plant Protec 6(1):57-63.

72. Mashingaizdze, A. B, (2004). Improving weed management and crop productivity in maize systems in Zimbabwe. PhD thesis. Wageningen University, Wageningen, Netherlands.

73. Matt L., and Dyck, E. (1993). Crop rotation and intercropping strategies for weed management. Ecol. Appl., vol. 3: 92-122,

74. Mawusi, D. M (2013). The effect of fertilizer formulation on yield components and yield of hybrid maize (*Zea mays* L.) varieties in the Guinea savannah zone of Ghana. Dissertation submitted to the Department of Crop Science, University of Ghana for award of Mphil. Agron P. 32-33

75. Mead R. and Willey R.W. (1980). The concept of Land Equivalent Ratio and advantages in yields from intercropping. Exp. Agric. 16:217-228

76. Midmore, D.J. (1993). Agronomy modification of resource use and intercrop productivity. Fixed crop Research, 34: 357-380

77. MOFA, (2010). Raw data on production, area cultivated and yield on various crops.

78. MOFA (Ministry of Food and Agriculture), (2011). "Agriculture in Ghana: Facts and Figures" Statistics, Research and Information Directorate. Accra, Ghana.

79. Monteith, J.L., (1977). Climate and the efficiency of crop production in Britain. Philosophical Transactions of the Royal Society of London Series B- Biological Sciences 281, 277–294.

80. Morgado, I.B. and Rao, M .R. (1985). População de plantas e níveis de água no consórcio milho x caupi. Pesquisa Agropecuária Brasileira, Brasília, 20:45-55,

81. Motsara, M.R. and Roy, R.N. (2008) Guide to laboratory establishment for nutrient analysis. FAO of the UN Rome.

82. Myaka, F. A. (1995). Effect of time of planting and planting pattern of different cowpea and maize in tropical sub-humid environment. Trop sci. 35: 274-279.

83. Norman. D. W. (1975) Rationalising mixed cropping under indigenous conditions. The example of Northern Nigeria. Samaru Agric. Bull. 232: 3-21.

84. Ntare B. R. (1990). Intercropping morphologically different cowpea with pear millet in a short season environment in the Sahel. Exp. Agric. 26:4-8

85. Nuttall, W. F., (2012). The effect of time of S application on yield and Sulphur uptake of canola. Commun, Soil.sci. Plant Anal. 22 ; 269;281

86. Odhiambo, G.D. and Ariga E.S. (2001). Effect of intercropping maize and beans on striga incidence and grain yield.Seventh Eastern and Southern Africa Regional Maize Conference, 183-186.

87. Okigho, B.N.and Greenland, D.J. (1976). Intercropping systems in tropical Africa. In: Papandick,R.I.; Sanchez, P.A.;Ttriplett, G.B. (Eds.). Multiple cropping. Madison: American Society of Agronomy. P.63-101.

88. Olasantan, F. O., Lucas, E. O. and Ezumah, H. C. (1994). Effects of intercropping and fertilizer application on weed control and performance of cassava and maize. Field Crops Res., vol. 39: 63-69,

89. Olowe V.I.O. and Adeyemo A.Y. (2009). Enhanced crop productivity and compatibility through intercropping of sesame and sunflower varieties. Ann Appl Biol

155:285-291.

90. Peace Corps (1981). Traditional Field Crops. P. 283.

91. Poggio, S. L. (2005). Structure of weed communities occurring in monoculture and intercropping of field pea and barley. J Agric Ecosys Environ 109:48-58.

92. Quayyum, M. A., Akanda and Karim M. F. (1987). Row spacing and number of rows of chickpea grown in association with maize (*zea mays L.*). Bangladesh J. Agril. Res. 12(4) : 223-230

93. Redy,R.C; Visser P. and Bucker R. (1992). Pear millet and cowpea yield in sole and intercrop system and their effect on soil and crop productivity. Field Crop Ressearch 28: 318-326.

94. Russell, G., Jarvis, P.G., Monteith, J.L., (1989). Absorption of radiation by canopies and stand growth. In: Russell, G. (Ed.), Plant Canopy: Their Growth, Form and Function. Cambridge University Press, Cambridge, pp. 21–39.

95. Sallah, P. Y. K., Obeng-Antwi K. Asiedu E. A. Ewool M. B. and Dzah B. D.

(2003). “Recent Advances in the Development and Promotion of Quality Protein Maize in Ghana.” In Maize Revolution in West and Central Africa, edited by B. Badu-Apraku, 410–424. Ibadan, Nigeria: West and Central Africa Collaborative Maize Research Network/International Institute of Tropical Agriculture.

96. Santalla, M., Rodino A.P., Casquero P.A. and De Ron A.M. (2001). Interactions of bush bean intercropped with field and sweet maize. European J. Agron. **15:** 185-196.

97. Saudy, H.S., and El-Metwally I.M., (2009). Weed management under different patterns of sunflower-soybean intercropping. Journal of Central European Agriculture, 10(1): 41-52.

98. Shackel, K.A. and Hall, A.E., (1984). Effect of intercropping on water relations of sorghum and cowpea. Field Crops Research, Amsterdam, vol. 8:381-387.

99. Smith, R.T. and Atkinson, K. (1975). Techniques in Pedology. Elek Science, London. P. 27-28

100. Soria, J.R., Bazan A. and Fargas J. (1975). Investigation of intercropping in pest management in corn-cassava and bean- cassava intercropping. Experimental Agriculture, 32: 283-295.

101. Spliid N.H., Carter A. and Helweg, A. (2004). Non-agricultural use of pesticides-Environmental issues and alternatives. Pest Manage Sci 60:523.

102. Távora, F.J.A.F. and Lopes, L.H. (1990). Deficiência hídrica no consórcio milho x cowpea. Pesquisa Agropecuária Brasileira, Brasília, vol.25:1011-1022.

103. Vandermeer J. H. (1989). The Ecology of Intercropping. Cambridge University Press, Cambridge, UK.

104. WABS Consulting Ltd., (2008). „Draft report of Maize Value Chain Study in Ghana. Enhancing Efficiency and Competitiveness.

105. Wahua, T.A. and Millen J. (1998)**:** Handbook for field trials in Technical cooperation, GTZ Eschborn.

106. Wahua, T. A. T., Babalola, O., and Oken"Oven, M.E. (1981). Intercropping morphologically different types of maizewith cowpeas. Experimental Agriculture 17 (4), 407413

107. Walkley, A. and Black, I.A (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method.
Soil sci. 37:29-38

108. Wanic. M, Kostrzewska M, Jastrzebska M (2004). Role of intercrop sowing in weeds control for spring barley in cereal crops rotation. Fragm Agron 1(81):85-102.

109. Watiki, J., S. Mfukai, J.A. Banda and B.A. Keating, (1993). Radiation interception and growth of maize/cowpea intercrop as an affected by maize plantdensity and cow pea cultivar. Field Crop Research, 35: 123-133.

110. Webster, R.W. and Wilson, D.S.O. (1996)**:** An experimental design on intercropping of maize with bush bean in Tropical Agriculture, vol. 8: 9-12

111. Willey, R.W., (1979). Intercropping- its importance and research needs. Part 1: Competition and yield advantages. Field Crop Research, 32: 1-10.

112. Willey, R.W. (1990). Resource use in intercropping systems. Agricultural Water Management, Amsterdam, vol.17:.215-231.

113. Willey R.W. and Osiru D.S.O. (1997)**:** Studies on mixture of maize and cowpea (Phaseolus valgaris) with particular reference to plant population. Journal of Agricultural Science Cambridge 79: 517 – 529

114. Yadav R. S., and Yadav O. P., (2001). The performance of cultivars of pearl millet and cluster bean under sole cropping and intercropping systems in arid zone conditions in India. Exp. Agr. 37:231 240.

115. Zhang, F. and Li L. (2003). Using competitive and facultative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. Plant and

Soil, 248:305-312

APPENDICES

Hybrids Maize Varieties Cultivate in Ghana and their characteristics

Variety name	Year released	Origin/source or(Institute)	Maturity period(days)	Potential (tons/ha.)	Seed colour
PAN 12		South Africa	110	8	Yellow
PAN 53		Source Africa	110	6-7	White
Mamaba	1996	CIMMYT	110	4-6	White
Etubi	2000	CIMMYT	110	4-6	White

Source: Al-Hassan and Jatoe (2002) & Kanungwe, (2009)

Cost of inputs and other farm operations ha^{-1} for 2014 In Northern Ghana

Activity/Input	Units	Unit cost GHC	Cost (ha^{-1}) GHC

Land preparation			
Ploughing	2.5 acr.	40.00	100.00
Harrowing	2.5 acr.	20.00	50.00
Inputs			
Seed maize :			
Pan 53	16 kg	15.00	240.00
Etubi	16 kg	6.00	96.00
Mamaba	16 kg	6.00	96.00
Obatampa	16 kg	2.30	36.80
Cowpea seed:			
Songotra	15 kg	2.00	30.00
Sanzi	10 kg	2.00	20.00
Chemical fertilizer:			
NPK(15-15-15)	4 bags	100.00	400.00
S.A	2 bags	73.00	146.00
Insecticide:			
Lamda 2.5 E.C	3 litres	13.00	39.00
Labour			
Manual weeding	2.5 acr	40.00	100.00
Fertilizer application	2.5 acr	20.00	50.00
Insecticide application	2.5 acr	10.00	25.00
Maize harvesting	2.5 acr	40.00	100.00
Cowpea harvesting	2.5 acr	25.00	62.50
Shelling & drying Maize	2.5 acr	20.00	50.00
Threshing and drying Cowpea	2.5 acr	20.00	50.00

Analysis of Variance Table for Maize Grain yield (kg/ha)

Source	DF	SS	MS	F	P
Rep	3	1591111	530370		
Main	2	1.220E+07	6100373	4.61	0.0612
Error Rep*Main	6	7935567	1322594		
Sub	3	5.023E+07	1.674E+07	26.02	0.0000
Main*Sub	6	4371105	728518	1.13	0.3706
Error Rep*Main*Sub	27	1.737E+07	643375		

Total	47	9.370E+07			

Analysis of Variance Table for Cowpea grain yield kg/ha.

Source	DF	SS	MS	F	P
Rep	3	348044	116015		
Main	1	4813	4813	0.05	0.8443
Error Rep*Main	3	315239	105080		
Sub	3	93402	31134	1.02	0.4083
Main*Sub	3	392289	130763	4.27	0.0192
Error Rep*Main*Sub	18	551019	30612		
Total	31	1704806			

Analysis of Variance Table for maize Plant Harvest Index (HI)

Source	DF	SS	MS	F	P
Rep	3	195.89	65.295		
Main	2	1591.29	795.647	9.68	0.0132
Error Rep*Main	6	493.19	82.198		
Sub	3	1433.95	477.982	7.68	0.0007
Main*Sub	6	422.73	70.454	1.13	0.3705
Error Rep*Main*Sub	27	1679.89	62.218		
Total	47	5816.93			

Analysis of Variance Table for Hundred seed (100) seed wt. (g)

Source	DF	SS	MS	F	P
Rep	3	12.917	4.306		

Main	2	10.792	5.396	0.55	0.6051
Error Rep*Main	6	59.208	9.868		
Sub	3	341.417	113.806	28.09	0.0000
Main*Sub	6	16.208	2.701	0.67	0.6770
Error Rep*Main*Sub	27	109.375	4.051		
Total	47	549.917			

Analysis of Variance Table for Maize stover weight kg/ha.

Source	DF	SS	MS	F	P
Rep	3	80585.6	26862		
Main	2	5451246	2725623	1.31	0.3384
Error Rep*Main	6	1.253E+07	2088573		
Sub	3	1.942E+07	6472731	5.31	0.0052
Main*Sub	6	7361294	1226882	1.01	0.4418
Error Rep*Main*Sub	27	3.292E+07	1219289		
Total	47	7.776E+07			

Analysis of Variance Table for maize Shelling %

Source	DF	SS	MS	F	P
Rep	3	89.80	29.934		
Main	2	414.87	207.436	1.04	0.4107
Error Rep*Main	6	1201.32	200.219		
Sub	3	326.99	108.995	0.79	0.5090
Main*Sub	6	425.45	70.908	0.52	0.7915
Error Rep*Main*Sub	27	3716.13	137.634		
Total	47	6174.56			

Analysis of Variance Table for % Light intercepted (PAR) (4WAP)

Source	DF	SS	MS	F	P
Rep	3	124.06	41.3544		
Main	2	191.20	95.6003	1.81	0.2425
Error Rep*Main	6	316.76	52.7933		
Sub	3	45.45	15.1506	1.04	0.3912
Main*Sub	6	118.94	19.8233	1.36	0.2664
Error Rep*Main*Sub	27	393.77	14.5841		
Total	47	1190.19			

Analysis of Variance Table for % Light intercepted (PAR) (6WAP)

Source	DF	SS	MS	F	P
Rep	3	303.73	101.243		
Main	2	401.37	200.687	2.29	0.1829
Error Rep*Main	6	526.94	87.823		
Sub	3	207.88	69.293	2.39	0.0909
Main*Sub	6	202.29	33.716	1.16	0.3550
Error Rep*Main*Sub	27	783.14	29.005		
Total	47	2425.35			

Analysis of Variance Table for % Light intercepted (PAR) (8WAP)

Source	DF	SS	MS	F	P
Rep	3	252.20	84.07		
Main	2	3542.74	1771.37	13.50	0.0060

Error Rep*Main	6	787.18	131.20		
Sub	3	402.65	134.22	2.48	0.0828
Main*Sub	6	450.15	75.03	1.38	0.2567
Error Rep*Main*Sub	27	1463.22	54.19		
Total	47	6898.14			

Analysis of Variance Table for % Light intercepted (PAR) (10WAP)

Source	DF	SS	MS	F	P
Rep	3	543.65	181.218		
Main	2	586.64	293.319	3.76	0.0874
Error Rep*Main	6	468.16	78.026		
Sub	3	268.56	89.520	1.77	0.1766
Main*Sub	6	365.80	60.967	1.21	0.3337
Error Rep*Main*Sub	27	1365.53	50.575		
Total	47	3598.34			

Analysis of Variance Table for Leaf Area Index (LAI) (4WAP)

Source	DF	SS	MS	F	P
Rep	3	6.2456	2.08186		
Main	2	1.7445	0.87226	1.76	0.2508
Error Rep*Main	6	2.9780	0.49632		
Sub	3	2.1165	0.70550	1.52	0.2314
Main*Sub	6	2.0813	0.34689	0.75	0.6160
Error Rep*Main*Sub	27	12.5149	0.46352		
Total	47	27.6808			

Analysis of Variance Table for Leaf Area Index (LAI) (6WAP)

Source	DF	SS	MS	F	P
Rep	3	2.9341	0.97803		
Main	2	3.0643	1.53216	18.16	0.0028
Error Rep*Main	6	0.5062	0.08436		
Sub	3	3.4660	1.15534	14.04	0.0000
Main*Sub	6	0.2255	0.03758	0.46	0.8338
Error Rep*Main*Sub	27	2.2213	0.08227		
Total	47	12.4174			

Analysis of Variance Table for Leaf Area Index (LAI) (8WAP)

Source	DF	SS	MS	F	P
Rep	3	1.9675	0.65583		
Main	2	3.1543	1.57716	3.50	0.0985
Error Rep*Main	6	2.7069	0.45115		
Sub	3	4.5158	1.50528	12.05	0.0000
Main*Sub	6	0.2490	0.04151	0.33	0.9139
Error Rep*Main*Sub	27	3.3728	0.12492		
Total	47	15.9664			

Analysis of Variance Table for Leaf Area Index (LAI) (10WAP)

Source	DF	SS	MS	F	P
Rep	3	1.9675	0.65583		
Main	2	3.1543	1.57716	3.50	0.0985
Error Rep*Main	6	2.7069	0.45115		

Sub	3	4.5158	1.50527	12.05	0.0000
Main*Sub	6	0.2490	0.04151	0.33	0.9139
Error Rep*Main*Sub	27	3.3728	0.12492		
Total	47	15.9664			

Analysis of Variance Table for Maize plant height cm (4WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	377.03	125.675		
Main	2	9.05	4.527	0.25	0.7858
Error Rep*Main	6	108.17	18.029		
Sub	3	244.14	81.382	3.49	0.0293
Main*Sub	6	131.15	21.858	0.94	0.4849
Error Rep*Main*Sub	27	629.76	23.324		
Total	47	1499.30			

Analysis of Variance Table for Maize plant height cm (6WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	709.5	236.495		
Main	2	429.2	214.605	0.31	0.7457
Error Rep*Main	6	4176.8	696.132		
Sub	3	538.6	179.530	0.80	0.5068
Main*Sub	6	1546.2	257.697	1.14	0.3651
Error Rep*Main*Sub	27	6088.1	225.484		
Total	47	13488.3			

Analysis of Variance Table for Maize plant height cm (8WAP)

Source	DF	SS	MS	F	P
Rep	3	715.7	238.57		
Main	2	625.2	312.60	3.73	0.0885
Error Rep*Main	6	502.6	83.76		
Sub	3	8355.0	2784.99	22.02	0.0000
Main*Sub	6	1203.5	200.59	1.59	0.1895
Error Rep*Main*Sub	27	3414.5	126.46		
Total	47	14816.5			

Analysis of Variance Table for Maize plant height cm(10WAP)

Source	DF	SS	MS	F	P
Rep	3	715.7	238.57		
Main	2	625.2	312.60	3.73	0.0885
Error Rep*Main	6	502.6	83.76		
Sub	3	8355.0	2784.99	22.02	0.0000
Main*Sub	6	1203.5	200.59	1.59	0.1895
Error Rep*Main*Sub	27	3414.5	126.46		
Total	47	14816.5			

Analysis of Variance Table Maize plant girth cm (4WAP)

Source	DF	SS	MS	F	P
Rep	3	1.4983	0.49944		
Main	2	0.5202	0.26011	0.44	0.6653
Error Rep*Main	6	3.5756	0.59592		
Sub	3	1.6106	0.53688	1.67	0.1961

Main*Sub	6	2.1799	0.36331	1.13	0.3703
Error Rep*Main*Sub	27	8.6597	0.32073		
Total	47	18.0442			

Analysis of Variance Table for Maize plant girth cm (6WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	2.3810	0.79365		
Main	2	1.5237	0.76186	1.31	0.3361
Error Rep*Main	6	3.4768	0.57947		
Sub	3	4.0801	1.36003	5.23	0.0056
Main*Sub	6	2.3640	0.39401	1.52	0.2106
Error Rep*Main*Sub	27	7.0150	0.25981		
Total	47	20.8406			

Analysis of Variance Table for Maize plant girth cm (8WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	2.1926	0.73086		
Main	2	12.2240	6.11198	4.09	0.0757
Error Rep*Main	6	8.9604	1.49339		
Sub	3	1.2860	0.42866	3.09	0.0439
Main*Sub	6	1.4430	0.24049	1.73	0.1519
Error Rep*Main*Sub	27	3.7500	0.13889		
Total	47	29.8558			

Analysis of Variance Table for Maize plant girth cm (10WAP)

Source	DF	SS	MS	F	P
Rep	3	1.3576	0.45253		
Main	2	11.0098	5.50489	3.16	0.1153
Error Rep*Main	6	10.4379	1.73964		
Sub	3	1.8826	0.62755	3.28	0.0361
Main*Sub	6	1.4488	0.24147	1.26	0.3076
Error Rep*Main*Sub	27	5.1675	0.19139		
Total	47	31.3041			

Analysis of Variance Table for SPAD value (4WAP)

Source	DF	SS	MS	F	P
Rep	3	40.024	13.3413		
Main	2	48.632	24.3158	1.77	0.2485
Error Rep*Main	6	82.334	13.7223		
Sub	3	250.258	83.4195	6.73	0.0016
Main*Sub	6	66.653	11.1089	0.90	0.5120
Error Rep*Main*Sub	27	334.773	12.3990		
Total	47	822.674			

Analysis of Variance Table for SPAD value (6WAP)

Source	DF	SS	MS	F	P
Rep	3	53.314	17.7713		
Main	2	90.442	45.2212	7.94	0.0206
Error Rep*Main	6	34.168	5.6946		
Sub	3	79.898	26.6328	2.10	0.1234

Main*Sub	6	92.652	15.4421	1.22	0.3273
Error Rep*Main*Sub	27	342.082	12.6697		
Total	47	692.557			

Analysis of Variance Table for SPAD value (8WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	40.04	13.345		
Main	2	281.35	140.676	4.39	0.0670
Error Rep*Main	6	192.39	32.064		
Sub	3	84.47	28.155	1.47	0.2442
Main*Sub	6	246.69	41.115	2.15	0.0800
Error Rep*Main*Sub	27	516.21	19.119		
Total	47	1361.13			

Analysis of Variance Table for SPAD value (10WAP)

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	53.314	17.7713		
Main	2	90.442	45.2212	7.94	0.0206
Error Rep*Main	6	34.168	5.6946		
Sub	3	79.898	26.6328	2.10	0.1234
Main*Sub	6	92.652	15.4421	1.22	0.3273
Error Rep*Main*Sub	27	342.082	12.6697		
Total	47	692.557			

Analysis of Variance Table for Weed score (1)

Source	DF	SS	MS	F	P
Rep	3	1.2292	0.40972		
Main	2	0.5000	0.25000	1.80	0.2441
Error Rep*Main	6	0.8333	0.13889		
Sub	3	0.7292	0.24306	0.71	0.5520
Main*Sub	6	0.8333	0.13889	0.41	0.8671
Error Rep*Main*Sub	27	9.1875	0.34028		
Total	47	13.3125			

Analysis of Variance Table for Weed score (2)

Source	DF	SS	MS	F	P
Rep	3	0.1667	0.05556		
Main	2	1.6250	0.81250	6.88	0.0280
Error Rep*Main	6	0.7083	0.11806		
Sub	3	0.8333	0.27778	0.98	0.4152
Main*Sub	6	1.0417	0.17361	0.61	0.7165
Error Rep*Main*Sub	27	7.6250	0.28241		
Total	47	12.0000			

Analysis of Variance Table for Weed stover(kg/ha)

Source	DF	SS	MS	F	P
Rep	3	4001667	1333889		
Main	2	2.082E+07	1.041E+07	22.95	0.0015
Error Rep*Main	6	2722083	453681		
Sub	3	3876667	1292222	2.26	0.1048

Source	DF	SS	MS	F	P
Main*Sub	6	7397083	1232847	2.15	0.0798
Error Rep*Main*Sub	27	1.547E+07	573009		
Total	47	5.429E+07			

Analysis of Variance Table for Maize stover weight kg/ha.

Source	DF	SS	MS	F	P
Rep	3	80585.6	26862		
Main	2	5451246	2725623	1.31	0.3384
Error Rep*Main	6	1.253E+07	2088573		
Sub	3	1.942E+07	6472731	5.31	0.0052
Main*Sub	6	7361294	1226882	1.01	0.4418
Error Rep*Main*Sub	27	3.292E+07	1219289		
Total	47	7.776E+07			

Analysis of Variance Table for %VWC (4WAP)

Source	DF	SS	MS	F	P
Rep	3	71.825	23.9418		
Main	2	2.587	1.2935	0.14	0.8715
Error Rep*Main	6	55.144	9.1906		
Sub	3	14.222	4.7407	1.11	0.3605
Main*Sub	6	61.932	10.3220	2.43	0.0525
Error Rep*Main*Sub	27	114.858	4.2540		
Total	47	320.568			

Analysis of Variance Table for % VWC (6WAP)

Source	DF	SS	MS	F	P
Rep	3	17.350	5.7832		
Main	2	26.180	13.0900	4.78	0.0573
Error Rep*Main	6	16.431	2.7385		
Sub	3	7.991	2.6636	1.56	0.2214
Main*Sub	6	11.262	1.8771	1.10	0.3872
Error Rep*Main*Sub	27	46.024	1.7046		
Total	47	125.238			

NM Analysis of Variance Table for % VWC (8WAP)

Source	DF	SS	MS	F	P
Rep	3	17.350	5.7832		
Main	2	26.180	13.0900	4.78	0.0573
Error Rep*Main	6	16.431	2.7385		
Sub	3	7.991	2.6636	1.56	0.2214
Main*Sub	6	11.262	1.8771	1.10	0.3872
Error Rep*Main*Sub	27	46.024	1.7046		
Total	47	125.238			

Analysis of Variance Table for % VWC (10WAP)

Source	DF	SS	MS	F	P
Rep	3	71.825	23.9418		
Main	2	2.587	1.2935	0.14	0.8715
Error Rep*Main	6	55.144	9.1906		
Sub	3	14.222	4.7407	1.11	0.3605

Main*Sub	6	61.932	10.3220	2.43	0.0525
Error Rep*Main*Sub	27	114.858	4.2540		
Total	47	320.568			