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DEPARTMENT OF HORTICULTURE

YIELD AND POSTHARVEST QUALITY OF MAIZE (*Zea mays* L.) AND OKRA (*Abelmoschus esculentus* L. Moench) INTERCROPS AS INFLUENCED BY PLANT DENSITY ARRANGEMENT IN THE SAVANNAH AGRO-ECOZONE

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THEODORE EYRAM AVUKPOR

JUNE, 2015

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (M. Phil. POSTHARVEST PHYSIOLOGY) DEGREE

JUNE, 2015

DECLARATION

I hereby declare that this submission is the result of my own work and that it has not been submitted either in part or whole for any other degree elsewhere. Works by other authors have been duly acknowledged.

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DEDICATION

I dedicate this work to my parents Rev & Mrs. Avukpor and my God-parents Dr. & Mrs. Banful for the enormous and unflinching support they have offered me through this level of my education. God Bless you.

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ABSTRACT

The production of more food for the growing populations in the coming decades, while combating poverty and hunger at present, is a significant challenge to the developing nations. This study therefore sought to determine the yield and postharvest quality of maize and okra in an intercropping system and assessing its economic profitability. The study was conducted to assess the yield and quality of maize and okra intercrops as affected by plant density. The field experiment was carried out at the Research fields of International Institute of Tropical Agriculture (IITA) located at the Ghana Air Force Base fields in Tamale - Northern Ghana during the raining season (July, 2014 to November, 2014). A Randomized Complete Block Design (RCBD) was used with three replications for the field work; the laboratory experiments were laid in a Completely Randomised Design (CRD) at the laboratory of the Department of Horticulture, KNUST and CSIR-Soil Research Institute. Maize was intercropped with okra in rows in the following ratio; 1 Maize :1 Okra, 1 Maize : 2 Okra, 2 Maize : 1 Okra, 2 Maize : 2 Okra and sole Maize and Sole Okra. The outcome of the study showed that, intercropping maize and okra resulted in the decrease in the striga population on the maize and an exponential increase in the number of pods of okra. Intercropping did not have any significant effect ($p<0.05$) on the yield of both component crops. In terms of postharvest qualities of the component crops, all the intercropping arrangements significantly ($p<0.01$) improved the calcium content of the okra fruits but did not have any significant ($p>0.01$) effect on crude protein, crude fibre, carbohydrates and fats of maize grain as well as TSS, TTA, pH and sugar-acid ratio of okra pods. Generally, this present study has demonstrated that intercropping maize with okra in various plant arrangements did not affect the postharvest quality of the maize whiles improving the

pod quality of the okra. Consequently, the two crops can be intercropped without the loss of any nutritional or chemical quality of either component crop in the system. Economically, intercropping maize and okra is highly profitable, with the level of profitability increasing as the population of okra in the intercrop system is increased. In addition, the cost of producing maize alone is high and erodes the percentage of profit accrued to the production of the crop.

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LIST OF ABBREVIATIONS

ABSF	African Biotechnology Stakeholders Forum
ADF	Acid Detergent Fiber
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CSIR	Council for Scientific and Industrial Research
CRD	Complete Randomised Design
DM	Dry Matter
DTMA	Drought Tolerant Maize for Africa
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
HSD	Honest Significant Difference
IITA	International Institute of Tropical Agriculture
ISO	International Organisation of Standardization
LAI	Leaf Area Index
LER	Land Equivalent Ratio
MiDA	Millennium Development Authority
MuFAS	Monounsaturated Fatty Acids
NDF	Neutral Detergent Fiber
NSP	Non-starch Polysaccharides

PD-CAAS	Protein Digestibility-Corrected Amino Acid Score
PLS	Percentage of Land Saved
PTH	Parathyroid Hormone
RCBD	Random Completely Block Design
SARI	Savannah Research Institute
SAS	Statistical Analysis Software
SFAs	Saturated Fatty Acids
TA	Titratable Acid
TB	Titratable Base
TCP	Total Cost of Production
TR	Total Revenue
TSS	Total Soluble Solids
TTA	Total Titritable Acidity
WAP	Week After Planting
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops after wheat, contributing substantially to the total cereal grain production in the world's economy as a food, feed, trade and industrial grain crop (Pingali, 2001; FAO, 2009). It was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability such that it can be grown in diverse seasons, ecologies and uses (Kamara *et al.,* 2005). It is grown on more than 96.5 million hectares of land in the third world countries, is the most dominant food crop and the mainstay diet to millions of people in Sub Saharan Africa (FAOSTAT, 2004).

According to ABSF, (2010) maize is the most widely grown and consumed staple crop with more than 300 million people depending on it as their main food source in Africa. Maize accounts for 15-20% of the total daily calories in the diets of more than 20 developing countries and the most important cereal crop in Sub-Saharan Africa (Adetiminrin *et al.,* 2008). In Ghana, maize is the most important staple food produced and consumed leading to an increase in production since 1965 (FAO, 2008; Morris *et al.,* 1999). In terms of area cultivated, maize is the number one crop accounting for 50 - 60 % of total cereal production second only to cocoa in acreage (MiDA, 2010; DTMA, 2013).

Okra (*Abelmoschus esculentus* L. Moench) was domesticated in West and Central Africa, but its original home is Ethiopia and Sudan (Schipper, 2000). It is one of the oldest cultivated crops and presently grown in many countries and is widely distributed through Africa, Asia, southern Europe and America (Kamara *et al;* 2005).

It is a nutritious vegetable, rich in vitamins, calcium, potassium and other minerals (Poggio, 2005). The immature pods are used in the form of boiled vegetable while dried form is used as soup thickener (Yadev *and* Dhanker, 2002).

Over the years, the intercropping of crops has been a common practice by smallholder and peasant farmers. Intercropping, which is the simultaneous cultivation of two or more crops on the same piece of land is the predominant practice in traditional farming systems of the tropics, including Ghana (Fawusi, 1985). The production of more food for the growing populations in the coming decades, while combating poverty and hunger at present, is a significant challenge to the developing nations. Intercropping principal food crops therefore to intensify resource use, is considered a key factor in meeting this challenge (Garrity *et al.,* 2010).

According to Alexandratos and Bruinsma (2012), food supplies would need to increase by 60% (estimated at 2005 food production levels) in order to meet the food demand in 2050. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing postharvest losses at the farm, retail and consumer levels (Alexandratos and Bruinsma, 2012). Intercropping not only minimizes risks due to crop failure under adverse environmental conditions but also gives a higher total return per unit area of land (Ijoyah and Jimba, 2011).

In Ghana, particularly, in the savanna agro-ecological zone, smallholder farmers intercrop maize with other crops because they want to take advantage of all the benefits of intercropping including balanced nutrition. This implies that vegetables need to be included in the system. However, the efficiency of the envisaged system with vegetables relies mostly on the in-built efficiency of the several crops that form the system and slightly on the additive effect amongst the crops. Presently however, there

is a dearth of information on maize-okra intercrop system in terms of yield and the nutritional quality of the intercrops in the system. The general objective of the study therefore was to determine yield, nutritional and postharvest quality response of maize and okra in maize – okra intercrop system at various plant populations and density arrangements. Specifically, the objectives were to determine the:

1. effects of different plant arrangements on yield of maize and okra intercrops;
2. effects of different plant arrangements on the postharvest nutrient and chemical quality of maize and okra fruits; and
3. economic profitability of the different intercropping systems.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 MAIZE GROWTH AND REPRODUCTIVE BIOLOGY

Maize belongs to the tribe Maydeae of the grass family *Poaceae*. Maize is a tallgrowing, determinate, monoecious, annual C4 plant altering in height between 1 to 4 metres giving rise to large, narrow, alternating leaves borne oppositely along the solid stem. The growth of maize is largely divided into the vegetative phases and reproductive phases. The vegetative phase entails;

1. Seedling/Sprouting phase which follows about one week afterwards planting and the plants possess between 2-4 leaves.
2. Grand growth phase also known as the knee height stage of plants comes between 35-45 days after planting.
3. Tasseling/Flower initiation phase, male flowers appear. Conventionally, the maize plant must have gained its full length by this phase.

The reproductive phases of maize comprise;

1. Silking stage which involves the formation of the female flowers or cobs is the first reproductive stage and happens about 2-3 days after tasseling stage. This stage starts when any of the silks are visibly showing on the husk. These are auxillary flowers unlike the male flowers (tassels) that are terminal ones. Pollination comes about when these new moist silks catch the falling pollen grains. Soft-dough/Milky stage which starts after pollination and fertilization has occurred. Grains begin developing but they do not become hard. This soft dough stage is identified by the silks on top of the cob which remains partly green at this stage and so do the coverings on the cobs also remain green.

2. Hard- dough/Maturity stage signifies that the leaves are dried; silks are dried totally and become brittle. At this stage, harvesting is done.

2.2 PESTS OF MAIZE

2.2.1 Striga Infestations

Striga weed, (*Striga hermonthica* (Del.) Benth) is a root parasitic flowering plant, found mostly in the Sub-Saharan Africa (SSA) causing acute constraints to crop production. Its survival is by channeling nutrients, which are meant for cereal crops such as maize (*Zea mays* [L.]), sorghum (*Sorghum bicolor* [L.]), pearl millet (*Pennisetum glaucum* [L.]), finger millet (*Eleusine coracana* [L.] Gaertn) and upland rice (both *Oryza glaberrima* [Steudel] and *O. sativa* [L.]) (Rodenburg *et al*., 2006; Atera *et al*., 2011). Underground, the parasitic weed diverts water and nutrients for its growth, while above the ground, the main crop stunts and grain yield is severely impacted (Khan *et al*., 2007).

In addition, the striga epidemic has enlarged in severity and in size in most parts of Sub Saharan Africa as a result of monocropping and seed dormancy. The greatest damage occurs in the savannah agro ecozone which constitutes the major areas of cereal production. Cereal yield losses due to striga vary from about 10% (at low levels of infestation) to complete crop loss and total abandonment of cereal production in severely infested fields. These losses were amounted at 10.7 million tons per year in sub-Saharan Africa (Gressel *et al.* 2004). Most of the yield loss (about 75%) occurs before striga emergence (Parker and Riches, 1993). The parasitic weed produces large amount of seeds, which are often ploughed into the soil during tillage (Atera *et al.*, 2012). Research carried out in western Kenya to assess the tolerance and resistance of rice cultivars also indicated that intense striga constraints led to total crop failure

(Kouko *et al*., 1992). The striga reaction on the biomass of the NERICAs expressed as percentage of susceptible Dourado precoce ranged between 40-66%. Dry matter of infected plots was lower compared to uninfected (Atera *et al.*, 2012). Comparable results have been reported in infected sorghum biomass being lower that of uninfected plants (Frost *et al*., 1997). Again, Aflakpui *et al*. (2002) reported that shoot biomass of infected maize before any striga had emerged above ground (at four-leaf stage) was about 93% that of uninfected maize but by the 18-leaf stage it was only 37% that of uninfected maize.

Crop yield loss due to striga attacks can vary depending on striga seed density, soil fertility, rainfall distribution, the cereal host species and variety grown; several control methods against Striga species have been recommended such as crop rotation, land fallowing, trap cropping, weeding and use of fertilizers. Others include the use of germination stimulants (Ariga and Berner, 1993) herbicides, host resistance (Radi 2007), and biological control (Abbasher and Sauerborn, 1992). Moreover, used alone, none of these methods has given a satisfactory suppression of the parasite (Ciotola *et al.* 1995). Nowadays, an integrated approach to striga management is gaining popularity and generally favoured over the use of any single control method (Mourik, 2007). The use of soil borne microorganisms as biological endogenous agents to striga has been investigated in West Africa. Fungi (Ciotola *et al.,* 1995, Marley *et al.,* 1999, Yonli *et al.,* 2006) and bacteria (Ahonsi *et al.,* 2002) have been suggested as components of integrated Striga management strategies. Ciotola *et al.* (2000) concluded from their work that the use of Fusarium oxysporum combined with other control measures could contribute to an effective strategy to control striga.

2.3 OKRA GROWTH AND REPRODUCTIVE BIOLOGY

Okra is chiefly seed propagated and has duration of 90-100 days. It is generally an annual crop. It has a robust stem, erect, and varies in branching from 0.5 to 4.0 metres in height. Leaves alternate and mostly are palmately five lobed, with an axillary and solitary flower. Indeterminate growth is characteristic of okra plants. Okra flowers continuously but mostly reliant on abiotic and biotic stress. Its first flower is borne one to two months after sowing. Flower bud initiation, flowering, anthesis and stigma receptivity are influenced by genotype and climatic factors like temperature and humidity (Venkatramini, 1952). The fruit is a capsule and grows quickly after flowering. The greatest increase in fruit length, height and diameter occurs during 4th to 6th day after pollination. It is at this stage that fruit is most often plucked for consumption. The okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous. Generally the fibre production in the fruit starts from 6th day onwards of fruit formation and a sudden increase in fibre content from 9th day is observed (Nath, 1976). Flowering continues for okra plants for an indefinite time and it is dependent on varietal, seasonal, soil moisture and fertility. Consistent harvesting stimulates continued fruiting; hence it may be necessary to harvest daily in climates where growth is especially vigorous.

2.4 INTERCROPPING SYSTEMS

Intercropping is the cultivation of two or more crops simultaneously on the same field (Ofori and Stern, 1987). It also means the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development. Intercropping is also known as mixed cropping and the component crops of an intercropping system may not necessarily be sown at the same time nor harvested

at the same time, but they should be grown simultaneously for a great part of their growth periods. (Anil *et al*., 1998; Ofori and Stern, 1987; Andrews and Kassam, 1976). It is a cropping practice that has been shown to have the potential of providing valuable ecosystem services such as improved pest control (Mitchell *et al.,*
2002; Daxl *et al*., 1994; Trenbath, 1993), increased resource use efficiency (Hauggaard-Nielsen *et al.,* 2001a; Keating and Carberry, 1993; Morris and Garrity, 1993), lowered weed infestation levels (Liebman and Dyck, 1993; Midmore, 1993), improved product quality (Anil *et al*., 1998), lower nitrate leaching (HauggaardNielsen *et al*., 2001b) and improved soil fertility and conservation (Daxl *et al*., 1994) compared to sole cropping. This system helps farmers to manage more than one crop in the same farm field. According to Dakora (1996), intercropping is a common practice in many parts of Africa and as a traditional farming system receives such patronage as a result of declining land sizes and food security problems.

There is often a main crop and one or more crop(s) added in intercropping system, with the main crop being of primary importance for economic or food production reasons. The two or more crops in an intercrop normally are from different species and different plant families, or less commonly they may be simply different varieties or cultivars of the same crop, such as mixing two or more kinds of wheat seed in the same field (Lithourgidis *et al*., 2011).

2.4.1 Intercrop Plant Arrangements

In intercrop plant arrangements, plants order (arrangements) affects the amount of light transmitted to crops beneath the canopy and increases the competition of component crops for light, water, and nutrients. Andrews and Kassam (1976) identified four main intercrop types:

(i) Mixed intercrops: component crops grown simultaneously in no definite row arrangements;

(ii) Row intercrops: component crops grown simultaneously in different rows;

(iii) Strip intercrops: component crops grown simultaneously in different strips to permit independent cultivation of each crop and

(iv) Relay intercrops: component crops grown in relay, so that growth cycles overlap.

2.4.2 Economic Importance of Intercropping

The main advantage of intercropping is the more economic use of the available growth resources and the increased productivity compared with each sole crop of the mixture (Jannasch and Martin, 1999; Hauggaard-Nielsen and Jensen, 2001; Zhang and Li, 2003; Szumigalski and Van Acker, 2006; Ofosu-Anim and Limbani, 2007; Agegnehu *et al*., 2008; Launay *et al*., 2009; Mucheru-Muna *et al*., 2010). Yield advantage occurs because growth resources such as light, water, and nutrients are more completely absorbed and converted to crop biomass by the intercrop over time and space (Tsubo *et al*., 2001, Joliffe 1997).

Total system light interception is determined by crop geometry and foliage architecture (Trenbath, 1983). For instance, Tsubo *et al.* (2001) reported that the radiation intercepted was higher in maize-bean intercropping than of the sole crop. The availability of water is one of the most important factors determining productivity in cereal-legume intercropping systems. Improvement of water use efficiency in these systems tend to increase the use of other resources (Hook and Gascho, 1988), and these intercrops have early high leaf area index and higher leaf area and therefore conserve a large amount of water (Ogindo and Walker, 2005). Increased nutrient uptake in

intercropping systems can occur spatially and temporally (Anders *et al*., 1996). Also, if the species have different rooting and uptake patterns, such as cereal/legume intercropping system, more efficient use of available nutrients may occur and higher N-uptake in the intercrop have been reported compared to monocrops (Fujita and Ofosu-Budu, 1996). Regularly intercropped pigeon pea or cowpea can help to maintain maize yield to some extent when maize is grown without mineral fertilizer on sandy soils in sub-humid zones of Zimbabwe (Waddington *et al*., 2007). Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize alone (Ghanbari *et al*., 2010).

2.4.2.1 Disadvantages of intercropping

Depending on crops mixed, 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). Mechanization is a major intercropping problem. Machinery used for sowing, weeding, fertilizing, and harvesting are made for big uniform fields. Harvesting remains a great problem, but it may be more easily overcome where the intercrops are harvested for forage or grazed. In the developing countries, the work needed in the field is mainly done by hand with simple tools because intercropping is very labour intensive; on a large scale basis, mechanization is generally believed to be impossible or inefficient (Vandermeer, 1989).

2.4.2.2 Compatibility of component crops

The choice of compatible crops depends on the plant growth habit, land, light, and water and fertilizer utilization (Brintha and Seran, 2009). Careful planning is required when

selecting the component crops of a mixture, taking into account the environmental conditions of an area and the available crops or varieties. The choice of selecting the right crop is of importance in an intercropping system due to the fact that competition for growth resources could be reduced not only by spatial arrangement, but also to exploit available soil nutrients (Fisher, 1977).

Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N (Benites, McCollum, and Naderman, 1993; Chu, Shen, and Cao, 2004; Jensen, 1996), which is scarce in most soils small-scale farms of SSA (Mugwe *at al.,* 2011; Palm *et al.,* 1997). The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil. However, some combinations have negative effects on the yield of the components under intercropping system. For example, Mucuna (*Mucuna utilis*) when intercropped with maize was found lowering maize yields, while cowpeas (*Vigna sinensis*) and greengram (*Phaseolus aureus*) had much less effect on maize and where themselves tolerant to maize shade (Agboola and Fayemi, 1971). Odendo *et al.,* (2011) reported that maize-bean intercrop is predominant in eastern Africa, and whilst in southern Africa maize is intercropped with cowpeas, groundnuts and bamabara nuts. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight
(Lithourgidis *et al*., 2011).

2.5 POSTHARVEST QUALITY

According to ISO (2006), quality is the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs. Postharvest quality entails nutritional quality, transport quality, edible quality, internal quality, table quality,

market quality and appearance quality. Consumers count good quality with respect to colour, flavour and nutrition. Quality of the produce is the final manifestation of inter-relation between the commodity and its environment. Field observations over the past 40 years have reported that 40 to 50% of horticultural crops produced in developing countries are lost in quality and quantity terms long before they can be consumed, mainly because of high rates of bruising, water loss and subsequent decay during postharvest handling (Kitinoja, 2002; Ray and Ravi, 2005).

Losses can also show up as decreased nutritional quality (loss of vitamins, minerals, deterioration resulting in high pH, development of health dangers such as mycotoxins) or decreased market value. Odeyemi and Daramola, (2000) reported that to preserve the quality of the food commodities so as to prevent food wastage and make food available all the time an important objective. The climatic factors such as sunshine, rainfall, humidity and temperature, influence condition during storage and may have a direct or indirect effect on the food rendering a decline in numbers and its nutritional quality. These changes however, do not necessarily render the food unfit for human consumption but they make it less palatable and sometimes unacceptable to the consumer.

During postharvest handling, the produce is susceptible to physical damage and deterioration. Horticultural produce losses are as high as 50% due to inefficient postharvest procedures (Camargo and Perdas, 2002). However, produce losses vary widely depending on the type of produce, marketing time and the production region. Losses also vary because different methods for assessing losses may be used and methods are rarely reported (Kader, 2002). Losses are estimated at 20-40% in developing countries and 10-15% in developed countries, depending on the crop. In the

EU, an estimated 4 billion EUR is lost due to postharvest losses and reduced quality of food produce especially vegetable fruits. Cortez *et al.,* (2002) estimated that, about half of the losses are due to physical injuries and improper handling during storage and distribution. Presently, the percent loss of vegetable crops in Ghana was estimated at 20% with most losses occurring during harvesting, transportation, storage and grading and sorting (Egyir *et al.,* 2008). However, quality are those characteristics that consumers associate each commodity with and which are dependent upon the particular end-use, such as sweetness, tenderness and crispness; although not considering the loss of quality in chemical and nutrition of food products because it is not an index for buying at the point of sale. Quality also refers to freedom from defects such as blemishes, mechanical injury, physiological disorders, water loss and decay. It is imperative to understand that, quality loss in fresh vegetable crops is cumulative: each incident of mishandling reduces the ultimate physical, chemical and the nutritional quality presented to the consumer. Again, many pre-harvest and postharvest factors such as genetics, cultural practices, planting period, planting density, irrigation, fertilization, crop protection, maturity at harvest and postharvest handling techniques influence composition and quality of produce by the time it reaches the consumer.

2.5.1 Proximate Analysis

Proximate and nutrient analysis entails moisture content, carbohydrate, crude fiber, crude protein, fat, ash and minerals.

2.5.1.1 Moisture content

Moisture is the measure of the water content of a material and is an important factor in food quality preservation and resistance to deterioration (Aurand *et al*., 1987). The moisture content of foods is of great importance for many scientific, technical and economic reasons. Moisture content must be known in determining the nutritive value

of a food, in expressing results of analytical determinations on a uniform basis, and in meeting compositional standards or laws. And finally, it is often desirable to weigh samples for analytical determinations on a given moisture basis. This is especially important if the measured analytical parameter does not vary in a linear or simple manner with an increase in dry matter content (Pomeranz and Meloan, 1987).

Products with relatively low moisture content should have good storage properties (Akpapunam and Sefa-Dedeh, 1995). It therefore follows that the lower the moisture content of a product, the longer the shelf life of the product.

2.5.1.2 Carbohydrates

Dietary carbohydrates are a diverse group of substances with a range of chemical, physical, and physiological properties (Cummings and Stephen, 2007). As the term implies, carbohydrates are based on the elements carbon, hydrogen, and oxygen (Gillespie *et al*., 1992). However, carbohydrates in foods comprise a great variety of structures, which in turn determine a wide range of physiological effects in the human body. Primary classifications of carbohydrates are based on chemistry, and since the early 1900s carbohydrates have been classified according to their chain length (Pereira and Liu, 2003). The term *complex carbohydrates* function was to distinguish sugars (simple sugars) from other carbohydrates and in the report it meant fruits, vegetables, and cereals. At present the term c*omplex carbohydrates* usually refers to starch alone or the combination of all polysaccharides, or it can be defined as either starch or fibre (Griel *et al*., 2006). However, the term has not been formally defined.

Simple sugars (*simple carbohydrates*) refer to monosaccharides and disaccharides (Cummings and Stephen, 2007).

Starch is the principal carbohydrate in diets worldwide; it is the storage carbohydrate of plants such as cereals, root vegetables, and legumes and consists of only glucose molecules (Cummings and Stephen, 2007). Carbohydrates have been separated into three major categories based on digestion; rapidly digestible, slowly digestible, and resistant (Sands *et al.*, 2009). Rapidly digestible carbohydrates are generally digested within 20 minutes while slowly digested carbohydrates can take between 20 and 120 minutes (Sands *et al*., 2009). Resistant carbohydrates, such as some legumes, consist of those that are not digested or absorbed in the small intestines (Sands *et al*., 2009).

There have been major leaps in the understanding of how carbohydrates affect human nutrition and health in recent years. Progress in scientific research has highlighted the diverse functions of carbohydrates in the body and their importance in the promotion of good health. Carbohydrates are one of the three major macronutrients which supply the body with energy (fat and protein being the others). The average adult diet contains at least 50% of the total calorie intake from carbohydrates (Holmes, 1971). There is now good evidence that at least 55% of our daily calories should come from carbohydrates. Whereas it is important to maintain an appropriate balance between calorie intake and expenditure, scientific studies suggest that:

1. A diet containing an optimum level of carbohydrates may help prevent body fat accumulation;
2. Starch and sugars provide readily accessible fuel for physical performance;
3. Dietary fibre, which is a carbohydrate, helps keep the bowel functioning correctly.

Carbohydrates play several crucial roles in the metabolic processes of living organisms. They serve as energy sources and as structural elements in living cells. The major function of carbohydrates is to provide energy and act as a source of fuel to the working

body (Smolin & Grosvenor, 2003). Living cells are in a state of ceaseless activity. To maintain its "life," each cell depends on highly coordinated biochemical reactions. Carbohydrates are an important source of the energy that drives these reactions. Therefore, a carbohydrate that has the ability to provide sustained energy and maintain blood glucose might be ideal.

The main-energy nutrients found in rations are carbohydrates (Gillespie *et al.*, 1992). They are major constituent of vegetable food materials on DM basis and by far the biggest constituent of the food of domestic animals. Very little of it is found in the animal body. Carbohydrate is the most abundant form of energy in plant materials and, as such, is the most widely available source of energy (Pond and Maner, 1974). According to Blakely and Bade (1994) the carbohydrate content of a ration makes up the largest, although not all the energy requirements. Some energy is derived from fats and oils in some instances from protein. All carbohydrates have about the same gross energy content of about 17.5 MJ/Kg DM (McDonald, 2002). The foods richest in starch and sugars (carbohydrate sources) are the tubers and roots (e.g. cassava) and cereals (e.g. maize, sorghum, and millet).

In general, carbohydrates cannot be absorbed in their natural form and therefore must be digested to become useful (Guyton & Hall, 2000). Carbohydrate properties, such as digestion and absorption rate, viscosity, structural features, water-binding capacity and fermentation ability in the GI tract, are of vital importance for their nutritional effects (Asp, 1996). The basic process in carbohydrate digestion is considered to be hydrolysis (Holmes, 1971; Guyton & Hall, 2000). The majority of carbohydrates in the diet are polysaccharides and disaccharides (Guyton & Hall, 2000). Through the process of

hydrolysis these larger carbohydrates are broken down to the smaller final product, monosaccharides for absorption into the blood stream (Guyton & Hall, 2000).

2.5.1.3 Crude fibre content

Crude fibre includes, theoretically, materials that are indigestible in the human and animal organism. Crude fibre is a measure of the quantity of indigestible cellulose, pentosans, lignins, and other components of this type present in food (Aurand *et al*., 1987). The definition of dietary fibre stated by the American Association of Cereal Chemists goes as follows: "Dietary fibre is the edible parts of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. It includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibre exhibits one or more of either laxation, (faecal bulking and softening, increased frequency, and/or regulatory), blood cholesterol attenuation, and/or glucose attenuation" (Van der Kamp, 2004). It is determined as material insoluble in dilute acid and dilute alkali under specified conditions (Pomeranz and Meloan, 1987). These fibres protect the body against colon cancer, diabetes and cardiovascular illnesses (Ponka *et al*., 2005). Dietary fiber is typically plant cell wall materials that are not digested by endogenous enzymes (Turner and Lupton, 2011).

It is difficult to precisely define dietary fiber. Fiber has historically been defined as the balance between nutritional significance and availability of adequate analytical methods, thus adapting the definition to the analytical procedure instead of the physiological effect of the fiber fractions. Insoluble dietary fiber is not degraded by microbial fermentation and could increase fecal output.Crude fibre can be calculated based on the loss on ignition of the dried residue remaining after digestion of the

samples with 1.25 % sulphuric acid and 1.25 % sodium hydroxide solutions (AOAC, 1984). According to Gopalan *et al.* (2007) 100g of edible portion of maize recorded 2.7g after loss of ignition of the dried maize sample.

2.5.1.4 Crude protein

Proteins are macromolecules consisting of long chains of amino acid subunits. The defining characteristic of protein is its requisite amino (or imino) nitrogen group. The average content of nitrogen in dietary protein is about 16 percent by weight, so nitrogen metabolism is often considered to be synonymous with protein metabolism. Carbon, oxygen, and hydrogen are also abundant elements in proteins, and there is a smaller proportion of sulfur.

Protein is the major functional and structural component of all the cells. Moreover, the constituent amino acids of protein act as precursors of many coenzymes, hormones, nucleic acids, and other molecules essential for life. Thus an adequate supply of dietary protein is essential to maintain cellular integrity, function and reproduction. Proteins should be provided in terms of both quality and quantity. Protein quality refers to the amino acid content (Blakely and Bade, 1994). The concept of protein requirement includes both total nitrogen and indispensable amino acid requirements. The quantity and utilisation of indispensable amino acids is considered to be an indicator of dietary protein quality, which is usually assessed using the Protein Digestibility-Corrected Amino Acid Score (PD-CAAS). It is important to determine to what extent the nitrogen from dietary protein is retained in the body.

2.5.1.5 Crude fat content

Dietary fat consists of heterogeneous mixtures of triacylglycerols (triglycerides) and small proportions of phospholipids, glycolipids, monoacylglycerols, diacylglycerols and unsaponifiable fraction composed of fat soluble chemicals collectively designated as non-glyceride components. Fatty acids, the building blocks of various lipids, are classified into 3 groups: saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs).

Fats and oils are the commercially important group of substances classified as lipid (Abraham and Hron, 1992). They are important in the human diet and more than 90 % of the world production is used as food or as ingredient in food production. They are responsible to increase palatability of food by retaining flavours and produce saiety due to slow digestion. In body, all cells except erythrocytes and nervous system use fatty acids as source of energy. Ketone bodies which are the derivatives of these acids are used by the brain in starvation. Dietary fats facilitate absorption and transportation of fat soluble vitamins. These are the concentrated source of energy which provides 9 kCal per gram, more than twice as available from an equal mass of carbohydrates and proteins (Zubay, 1998). They serve as rich source of dietary energy. Their fatty acid components are essential nutrients, while their functional and textural characteristics contribute to the flavour and palatability of manufactured foods. Fat provides a convenient and concentrated source of energy, supplying more energy than the same weight of carbohydrate or protein and provides a source of the fat-soluble vitamins A, D, E and K (Tull, 1996).

2.5.1.6 Ash and Minerals

Ash is defined as the quantity of mineral matter which after combustion remains as incombustible residue of the tested substance (Pearson, 1976). The ash content is a measure of the total amount of minerals present within a food, whereas the mineral content is a measure of the amount of specific inorganic components present within a food, such as Ca, Na, K and Cl (McClements, 2003). The ash constituents include potassium, sodium, calcium and magnesium, which are present in larger amounts as well as smaller quantities of aluminum, iron, copper, manganese or zinc, arsenic, iodine, fluorine and other elements present in traces. There are two forms of minerals: macro and trace minerals. Macro means "large" and implies that they are required in larger quantity for body needs as compared to trace minerals. The examples of macro minerals are i.e. calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur. The mineral composition may be affected by the environmental and area locations (Bajaj *et al.,* 1991).

Determination of the ash and mineral content of foods is important for a number of reasons:

1. *Nutritional labeling.* The concentration and type of minerals present must often be stipulated on the label of a food.
2. *Quality.* The quality of many foods depends on the concentration and type of minerals they contain, including their taste, appearance, texture and stability.
3. *Microbiological stability.* High mineral contents are sometimes used to retard the growth of certain microorganisms.

4. *Nutrition.* Some minerals are essential to a healthy diet (*e.g.,* calcium, phosphorous, potassium and sodium) whereas others can be toxic (*e.g.,* lead, mercury, cadmium and aluminum).

Processing, it is often important to know the mineral content of foods during processing because this affects the physicochemical properties of foods (McClements, 2003). Minerals act as co-factors for many biological reactions within the body, including muscle contraction, neuro-transmission, production of hormones, digestion and utilization of nutrients (Champe and Harvey, 1994). The minerals are responsible for skeletal formation, maintenance of colloidal systems, regulation of acid-base equilibrium and for biologically important compounds. Mineral deficiencies can cause biochemical, structural and functional pathologies which depend on several factors, including the duration and degree of mineral deprivation. The physiological importance of minerals is well documented for humans and some animals. However, many aspects of intake, function and bioavailability of trace minerals are still unclear.

2.5.2.1 Calcium (Ca) and Phosphorus (P)

Calcium is used in large amounts by plants second only to N and K. It is a major component of the middle lamella (Ca-pectates) of the cell wall. It strengthens the cell walls, is involved in cell elongation and division, membrane permeability, and activation of several critical enzymes (Brady and Weil, 2008). In accordance with its functions, calcium influences crop and food quality. Calcium is less mobile such that its influence on crop quality is easily noted with foliar application. Nutritionally, calcium ensures proper muscle action, a regular heartbeat and steady concentration of ions both inside and outside body cells. It also plays a role in blood clotting (Mehas and Rodgers, 1997).

Phosphorus is closely linked with calcium. These two minerals combine to form calcium phosphate, which give bones their strength and rigid structure. Phosphorus is essential for the production of energy in the body. It forms parts of many proteins, and is often used as an additive in manufactured foods (Tull, 1996). Calcium and phosphorus are absorbed better by the body if consumed together. Eating equal amount of each mineral is considered best (Mehas and Rodgers, 1997). The absorption of calcium and phosphorus and the mineralization of bones and teeth are controlled by vitamin D. The body must have a sufficient supply of all three in order to function properly (Tull, 1996).

2.5.2.2 Potassium (K)

Potassium is an essential nutrient that is absorbed by plants in larger amounts than any other nutrient except N (Roy et al., 2006). Unlike N, P and most other nutrients, K is not incorporated into structures of organic compounds; instead potassium remains in ionic form (K+) in solution in the cell and acts as an activator of many cellular enzymes (Havlin *et al.,* 2005). Therefore, it has many functions in plant nutrition and growth that influence both yield and quality of the crop. These include regulation of metabolic processes such as photosynthesis; activation of enzymes that metabolize carbohydrates for synthesis of amino acids and proteins; facilitation of cell division and growth by helping to move starches and sugars between plant parts. It is reported that among the many plant mineral nutrients potassium (K) stands out as a cation having the strongest influence on quality attributes that determine fruit marketability, consumer preference, and the concentration of critically important human-health associated phyto-nutrients or bioactive compounds (ascorbic acid and Beta carotene) (Jifon and Lester, 2009; Jifon

et al., 2010). Potassium plays very vital role for the synthesis of proteins and cell functions.

2.5.2.3 Sodium (Na)

Sodium is the principal cation of extracellular fluid and is involved primarily in the maintenance of osmotic equilibrium and extracellular fluid volume. Sodium functions as the ―osmotic skeleton‖ of the extracellular fluid. Sodium ingested in the diet is absorbed from the gastrointestinal tract. Nutritionally, most dietary sodium is found in the form of sodium chloride, which is 40% sodium and 60% chloride. Therefore it is necessary to consider sodium requirements and the limits of safe intake in order to avoid metabolic consequences of excess intake of sodium chloride.

2.5.2.4 Magnesium (Mg)

Magnesium is another secondary nutrient element. It is important as a primary constituent of chlorophyll and as a structural component of ribosomes, it helps in their configuration for protein synthesis (Havlin *et al.,* 2005). It is also required for maximum activity of almost all phosphorylating enzymes in carbohydrate metabolism. Adequate levels of Mg in USA reported increased quality and profits of potato due to improved potato specific gravity (Hoyum, 2010). Increased specific gravity of potatoes can be attributed to increased carbohydrate synthesis and deposition from the leaves. Usually, the first things to be noticed due to influence of Mg are chlorophyll level, photosynthesis (photosynthetic CO2 fixation), and protein synthesis, however, recently, distribution of carbohydrates among shoot and root organs have been reported as well (Cakmak and Yazici, 2010).

These in turn affect quality of plant product depending on which part is used for food by humans or animals. Nutritionally, like calcium, magnesium is closely associated with skeletal system and is homeostatically regulated by calcitropic hormones. About 20-25g magnesium is present in adult human body and about 60-70% of it occurs in the bone, 25-30% in the muscle, 6-8% in soft tissues and 1% in the extracellular fluid.

2.5.2.5 Manganese (Mn)

The mitochondria have a greater concentration of manganese than cytoplasm or other cell organelles. Manganese is necessary for the normal functioning of brain and for proper lipid and carbohydrate metabolism. The mineral has two roles: first as a cofactor for enzymes which form metal-enzyme complexes; and second as an integral part of metalloenzymes. Manganese activates specific enzymes such as glycosyltransferase and non-specific enzymes such as kinases, transferases, hydrolases and decarboxylases. The activation of leucine aminopeptidase by manganese has been demonstrated in sole (Clark *et al*., 1987). An inadequate supply of manganese usually results in retardation of growth.

2.5.2.6 Copper (Cu)

Copper is important for animals as it is involved in the activity of enzymes such as cytochrome oxidase, superoxide dismutase, lysyl oxidase, dopamine hydroxylase and tyrosinase. In addition, copper-proteins and chelates also have metabolic roles. Copper levels are high in the eyes where it is found along with melanins, bound to protein. Organs such as liver, brain and heart also contain comparatively large amounts of copper. A copper-protein complex, ceruloplasmin, exhibiting oxidative activity, occurs in blood plasma.

2.5.2.7 Zinc (Zn)

It is involved in various metabolic pathways. It serves as a specific cofactor of several enzymes. In addition, zinc is an integral part of about 20 metalloenzymes such as alkaline phosphatase, alcohol dehydrogenase and carbonic anhydrase. Zinc is connected with prostaglandin metabolism and also may have a structural role in nucleoproteins. Zinc is an essential trace element in the diets of humans for optimal health and growth. Signs and symptoms of mild zinc deficiency in young children include impaired linear growth, poor weight gain, reduced deposition of lean body tissue, anorexia, hypogeusia and impaired immunocompetence (Ferguson *et al*., 1993).

2.5.2.8 Iron (Fe)

Iron has an active part in oxidation/reduction reactions and electron transport associated with cellular respiration. It is found in complexes bound to proteins such as haem, in enzymes such as microsomal cytochromes, catalase, etc., and in non-haem compounds such as transferrin, ferritin and flavin iron enzymes. Haemoglobin occurs in erythrocytes while transferrin is found in plasma; the latter is the principal carrier of iron in blood (Mehas and Rodgers, 1997).

2.5.2.9 Lead (Pb) and Cadmium (Cd)

The intake of heavy metals in food makes up a considerable amount of total contamination in humans. The ingestion of heavy metals in humans may be through food chain via directly or indirectly and to some extent it is also accumulated in the human body. Lead and cadmium are among the most abundant heavy metals and are particularly toxic. Exceeding level of these toxic may affect the health of individuals. Cadmium has shown adverse effects on kidney's role in human body, and some studies have reported it as a carcinogenic element (Merian, 1984). Lead is fewer toxic as

compared to cadmium. But the exceeding level may inhibit the enzyme functions in children (Scheffer and Schachtschabel, 1989).

These heavy metals have also an effect on plants because it higher level may reduce the crop yields. There are various sources of contamination of these heavy metals in food grains especially the use of contaminated water in grain fields may enhance the level of cadmium contents in grains. Contaminated soil may also be an important factor for higher intake of cadmium in grains.

2.6.1 Maturity Index for Fruits and Vegetables

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Postharvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit). Some typical maturity indexes are described in following sections.

2.6.1.1 Total Titratable Acidity (TTA) and pH

Titratable acid (TA) can be defined as the excess of acid in a solution determined by the amount of strong base it is necessary to add to the solution in order to produce a given final state. Titratable base (TB) can be defined as the excess of base in a solution determined by the amount of strong acid it is necessary to add to the solution in order

to produce a given final state. The final state is defined by the hydrogen ion concentration (activity), e.g. a pH of 7.4 in the case of urine, and as the hydrogen ion concentration varies with temperature the latter must also be specified. For a given final state a positive value for T.A. corresponds exactly to a negative value for T.B. Or in other words, an addition of strong acid is completely equivalent to the removal of strong base with respect to the acid-base conditions. The water concentration and the concentration of electrolytes will of course be different (Bronsted, 1923). Titratable acidity is the total amount of hydrogen ions/protons present in a sample with the exception of those bound to alkaline ions and is expressed as g/L tartaric acid equivalent. The hydrogen ions can be either attached to acids or in the form of free ions or anions. Titratable acidity is different than total acidity, although at times both terms are used to mean the same thing. Total acidity is the total amount of organic acids in a substance. This includes all wine acids (i.e. tartaric, malic and citric). The titratable acidity is always less than the total acidity, because not all of the hydrogen ions expected from the acids are found during the determination of titratable acidity. However, titratable acidity is easier to measure (Boulton, 1980). Titratable acidity analysis utilizes the pH endpoint of titration to determine the result. The titration begins with a known volume of the sample and a known concentration of sodium hydroxide. The sodium hydroxide is titrated into the sample. A pH meter measures the equivalence point or the point at which all of the available hydrogen ions in the sample have reacted with the sodium hydroxide. The volume of sodium hydroxide used to titrate to the pH endpoint is needed to determine the titratable acidity. Usually organic acids decline during ripening as they are respired or converted to sugar. Organic acid are important in giving a desired sugar-to- acid balance which result in pleasing fruit taste during ripening. Therefore titratable acidity could be used as an index of quality ripening during fruit

ripening. Since organic acids can be considered as a source of energy, their gradual decline during ripening might be explained by their utilization during postharvest respiration (Kader, 2002). The degree of decline in organic acids is dependent on cultivar, preharvest environmental and cultural factors as well as on postharvest storage- and handling conditions. Since acidity in interaction with sweetness mainly contributes to fruit flavour, it is considered to be an important quality factor (Kader, 2002).

Power of hydrogen (pH) is the equilibrium measure of hydrogen ion concentration in a substance. It is the logarithm of the concentration of free protons, expressed with a positive sign. pH is an important post-harvest quality attribute in the assessment of fruit ripening quality In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree. Normally, acidity is not taken as a measurement of fruit maturity by itself but in relation to soluble solids, giving what is termed the brix: acid ratio (FAO, 2003).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 DESCRIPTION OF EXPERIMENT SITE

The field experiment was carried out at the research fields of the International Institute of Tropical Agriculture (IITA) located in Tamale in Northern region from July, to November, 2014. Tamale is in the Guinea savannah zone with a unimodal rainfall distribution. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum

temperatures in December and January. The land is mostly flat with gentle undulating low relief between 60 metres and 150 metres above sea level. The soils are mainly, Savannah Ochrosols and Groundwater Lateritic soils.

3.2 SCOPE OF STUDY

The study comprised field and laboratory experiments. The field experiment focused on the agronomic performance of the intercrops whereas the laboratory experiment centred on the postharvest nutrient and chemical quality of the maize and okra as intercrops.

3.3 FIELD EXPERIMENTAL DESIGN AND TREATMENTS

The experimental design was Randomized Complete Block Design (RCBD) with three replications. There were six treatments, namely, (i) 1 (25,000 plants ha^{-1}) : 1 (25,000 plants ha^{-1}) = 1 row of maize : 1 row of okra (ii) 1 (25,000 plants ha^{-1}) : 2 (50,000 plants ha^{-1}) = 1 row of maize : 2 rows of okra (iii) 2 (50,000 plants ha^{-1}) : 1(25,000 plants ha^{-1}) =2 rows of maize : 1 row of okra (iv) 2 (50,000 plants ha^{-1}) : 2 (50,000 plants ha^{-1}) = 2 rows of maize : 2 rows of okra (v) Sole maize (31,250 plants ha^{-1}) (vi) Sole okra (41,666 plants ha^{-1}).

3.4 LAND PREPARATION AND EXPERIMENTAL PROCEDURE

The experimental area was ploughed and harrowed and the plots demarcated. Each experimental plot measured 8 metres by 4 metres (24 metres sq). Alleys between the replications were 2m while that between the plots of the same replication was 1m. A total of 18 plots were used and each plot consisted of a number of rows of maize and okra depending on the density and the arrangement.

The maize variety used in the study was Omankwa, a 90-day cultivar which is striga tolerant. The variety was developed by the CSIR- Savanna Agricultural Research Institute. The okra variety used was Clemson Spineless procured from a certified agro-input dealer in Tamale. At planting, three seeds were sown and thinned to two plants per hill for the maize and one plant per stand for the okra, three weeks after emergence to give the following final plant population density: 25000 plants ha^{-1} for both maize and okra under intercropping systems; 31250 plants ha^{-1} for sole maize and 41666 plants ha^{-1} for sole okra. Weeds were controlled by hand hoeing at three and five weeks after planting and thereafter as and when necessary. Basal application of compound fertilizer, NPK (15-15-15) was applied three weeks after planting and 125 kg of Sulphate of Ammonia as top dressing was applied six weeks after planting.

3.5 FIELD DATA COLLECTED

3.5.0 Data Sampling

Eighteen (18) plants for both maize and okra for all the intercropped plots and twentyseven (27) plants for sole maize and sole okra were all tagged for data collection.

3.5.1 Growth and Yield of Component Crops

3.5.1.1 Leaf area

The formulae proposed by Krishnamurthy *et al.* (1974) were used to determine the leaf area and leaf area index. For the leaf area, it is given as: **Leaf area= k (l x w)**

Where,

l= leaf length w= leaf width k= factor (in cereals= 0.75)

3.5.1.2 Number of pods/cobs per plant

This parameter was estimated at harvest by counting the number of pods of okra and cobs of maize on the eighteen tagged plants for both maize and okra plants under the intercropping systems and the twenty-seven tagged plants for both sole maize and sole okra plots and the mean recorded.

3.5.1.3 Okra pod / maize cob weight

With a digital balance, selected cobs or pods from the eighteen tagged plants for both maize and okra plants under the intercropping systems and the twenty-seven tagged plants for both sole maize and sole okra plots were weighed in grams (g) and the mean calculated.

3.5.1.4 Okra fruit yield

The eighteen tagged plants from the intercropping systems plots and the twenty-seven tagged plants of the sole okra plots were harvested at edible maturity stage and weighed to record pod yield per plot and then converted into pod yield per hectare (kg/ha) using the formula :

$$\textbf{Pod yield (kg/ha)} = \frac{Pod\ yield\ (kg)}{Harvested\ area\ (m^2)} \times \textbf{10,000m}^2$$

3.5.1.5 Maize grain yield

The cobs from the harvested eighteen tagged plants from the intercropping systems plots and the twenty-seven tagged plants of the sole maize plots were harvested, dehusked, decobbed, shelled and the weight of the grains (kg) was recorded and converted using the formula:

$$\textbf{Grain yield (kg/ha)} = \frac{Grain\ yield\ (kg)}{Harvested\ area\ (m^2)} \times \textbf{10,000m}^2$$

3.6 POST HARVEST QUALITY CHARACTERISTICS

3.6.1 Preparation of Maize and Okra Samples

About ten (10) freshly harvested okra fruits from the various treatments were taken; oven dried and powdered using a kitchen blender.

Maize cobs were de-shelled and about Eight grams (8g) of grains from the various treatments were collected, oven dried and powdered into flour for the nutritional and chemical analysis.

Filtrate Preparation

Two grams (2g) of the powdered samples were dissolved in hot distilled water and filtered. The filtrate was used in the determination of the quality parameters.

3.6.3 NUTRITIONAL COMPOSITION

3.6.3.1 PROXIMATE COMPOSITION

The following analyses were conducted; proximate analysis, Minerals, pH, Total Soluble Solids (TSS), Total Titratable Acidity (TTA), and Sugar Acid Ratio (TTA: TSS. Procedures of AOAC (1990) were used to determine the proximate composition of the component crops.

3.6.3.2 Moisture Content Determination

Two grams each of the samples was weighed into dried weighed crucibles. The sample was put into a moisture extraction oven at 105°C and heated for 3h. The dried sample was put into desiccators, allowed to cool and reweighed. This process was repeated until a constant weight is obtained. The difference between the weights was calculated percentage of the original sample.

$$\textbf{Percentage moisture} = \frac{W2 - W3}{W2 - W1} \times \mathbf{100}$$

Where, W1 = Initial weight of empty dish

W2 = Weight of dish + undried sample

W3 = Weight of dish + dried sample

3.6.3.3 Crude Protein Determination

The micro Kjeldahl method described by AOAC, (1990) was used. Two grams, each of the samples was mixed with 10 ml of concentrated H_2SO_4 in a heating tube. One tablet of selenium catalyst was added to the tube and mixture heated inside a fume cupboard. The digest was transferred into a 100 ml volumetric flask and made up with distilled water. Ten milliliter portion of the digest was mixed with equal volume of 45% NaOH solution and poured into a kjeldahl distillation apparatus. The mixture was distilled and the distillate collected into 4% boric acid solution containing 3 drops of zuazaga indicator. A total of 50 ml distillate was collected and titrated as well. The sample was duplicated and the average value taken. The nitrogen content was calculated and multiplied with 6.25 to obtain the crude protein content. This is given as Percentage of

$$\textbf{Nitrogen} = \frac{(100 \times N \times 14 \times Vf)T}{100 \times Va} \frac{W2 - W3}{W2 - W1}$$

Where;

W = Weight of the ample N =

Normality of the titrate (0.1N) vf =

Total volume of the digest = 100ml T =

Titre value va = Aliquot volume

distilled.

3.6.3.4 Crude fat content determination

Two grams sample was loosely wrapped with a filter paper and put into the thimble which was fitted to a clean round bottom flask, which has been cleaned, dried and weighed. The flask contained 120 ml of petroleum ether. The sample was heated with a heating mantle and allowed to reflux for 5 h. The heating was then stopped and the thimbles with the spent samples kept and later weighed. The difference in weight was recorded as mass of fat and was expressed as percentage of the sample.

The percentage oil content is calculated as;

$$\textbf{Percentage of Crude Fat} = \frac{W2-W1}{W3} \times 100$$

Where,

W1 = Weight of the empty extraction flask

W2 = Weight of the flask and oil extracted

W3 = Weight of the sample

3.6.3.5 Crude fibre determination

Two grams sample was put into 200 ml of 1.25% of H_2SO4 and boiled for 30 minutes. The solution and content was then poured into buchner funnel equipped with muslin cloth and secured with elastic band. This was allowed to filter and residue washed with hot water to free it from acid. The residue was then put into 200 ml boiling 1.25% NaOH and boiled for 30 min, then filtered. It was then washed twice with alcohol; the material obtained was washed thrice with petroleum ester. The residue obtained was put in a clean dry crucible and dried in the moisture extraction oven to a constant weight. The dried crucible was removed, cooled and weighed. The difference of weight (i.e. loss in ignition) is recorded as crucible fibre and expressed in percentage of the original weight.

$$\textbf{Percentage of Crude Fibre} = \frac{W1-W2}{Wt} \times 100$$

Where

W1 = Weight of sample before incineration

W2 = Weight of sample after incineration W3

= Weight of original sample.

3.6.3.6 Ash content determination

Two grams each of the samples was weighed into crucible, heated in a moisture extraction oven for 3 hours at 100°C before being transferred into a muffle furnace until it turned white and free of carbon. The sample was then removed from the furnace, cooled in desiccators to a room temperature and reweighed immediately. The weight of the residue was then calculated as ash content expressed in percentage.

$$\textbf{Percentage Ash} = \frac{Weight\ of\ Ash}{weight\ of\ Sample} \times 100$$

3.6.3.7 Carbohydrate content determination

The nitrogen free method described by AOAC was used. The carbohydrate is calculated as weight by difference between 100 and the summation of other proximate parameters as Nitrogen Free Extract (NFE); **(NFE) = 100 – (M + P + F1 + F2)**

Where; M = moisture

P = protein

F1 = fat

A = ash

F2 = fibre

3.6.3.8 Determination of mineral elements

The mineral elements were determined using the analytical method of determining mineral constituents of food products (Hack, 2000). Samples obtained through ashing

were used for this procedure which was the white fluffy mas. Five milliliter of concentrated hydrochloric acid was used to digest each of the ash content in a glass petri dish. The mixture was transferred into 50 ml chemical flask using distilled water. Particles which cannot dissolve and would cause contamination were filtered off using Whatman's no. 1 filter paper in a funnel. The new filtrate was made up to mark in readiness for mineral nutrient determination. The elements determined include Ca, N. K, P, Mg, Pb, Cu and Zn. The determination was made using the method described by (Hack, 2000) Standard reagents for the various elements to be determined were prepared. The series spectrophotometer was first warmed up for 30 minutes. Then, the standard reagents of the elements to be determined and distilled water were used to standardize the equipment. The samples contained in 10 ml cuvette were then introduced into the sample chamber where the digital score of the samples were read and recorded.

3.6.4 Chemical Composition

3.6.4.1 Determination of pH of okra pods

Two grams (2g) of the powdered okra sample was dissolved in 60 ml hot distilled water. The solution was stirred and allowed to cool for 30 minutes. The probe of pH WP Martin's instrument was dipped into the solution and pH readings taken.

3.6.4.2 Determination of total soluble solids (TSS) of okra pods

Total Soluble Solids was determined by pipetting 10µl of filtrate and onto the prism of a hand-held Refractometer (HI 9680 Refractometer) the TSS was determined. The results were expressed as ^{o}Brix (Cheour *et al.*, 1991).

3.6.4.3 Determination of Total Titratable Acidity (TTA) of okra pods

Two grams (2g) of the powdered okra was dissolved in hot distilled water, filtered and allowed to cool for about 30 minutes. Ten millilitres (10 ml) of the filtrate was transferred into conical flask. Three drops of phenolphthalein indicator was added. This solution was titrated against 0.1M sodium hydroxide until there was a sharp colour change from colourless to pink. The titre volume of NaOH added was multiplied by the citric acid factor (0.07) to obtain the total titratable acidity (Dadzie and Orchard, 1997).

3.6.5 Physical Quality Characteristics

3.6.5.1 Malformations/Defects.

At harvest, fruits from the eighteen tagged plants under the intercropping systems and the twenty-seven tagged plants from the sole okra plots were sorted into malformed or fruits with defects and the results expressed in percentages using the formula:

$$\textbf{Malformations} = \frac{Number\ of\ Malformed\ Fruits}{Total\ Harvested\ Fruits} \times 100$$

3.6.5.2 Marketable pod yield

At harvest, fruits from the eighteen tagged plants under the intercropping systems and the twenty-seven tagged plants from the sole okra plots were sorted into marketable and unmarketable pods and the results expressed in percentages using the formula:

$$\textbf{Marketable Pod Yield} = \frac{Number\ of\ Marketable\ Fruits}{Total\ Harvested\ Fruits} \times 100$$

3.7 COST-BENEFIT-ANALYSIS

3.7.1 Total Revenue (GhȻ/ha)

This was determined by finding the prevailing farm gate price of the produce and the total weights of the component crops for each system.

3.7.2 Total Cost of Production (GhȻ/ha)

This was determined by summing up all the costs incurred for the various activities undertaken for each system. For the intercropping systems, the differential cost of drying the quantity of maize obtained for each system was added to the cost.

3.7.3 Profit (GhȻ/ha)

This was determined by subtracting the total cost of production (TCP) from the total revenue (TR) as follows; $\boldsymbol{Profit = TR - TCP}$

3.8 DATA ANALYSIS

All data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS). Tukey's HSD (Honest Significant Difference) was used for mean separation. Probability levels of 0.05 and 0.01 were used for the field and laboratory experiments, respectively.

CHAPTER FOUR

4.0 RESULTS

4.1 EFFECTS OF INTERCROPPING ARRANGEMENTS ON MAIZE LEAF AREA AND STRIGA POPULATION.

There were no significant differences between treatments for maize leaf area. However, leaf area ranged between 481.1 cm^2 and 656.1 cm^2 (Table 4.1).

Table: 4.1 Leaf area of maize as affected by the maize-okra intercrop arrangements.

Crop Arrangements	Leaf Area (cm^2)	Number of Striga plants
1 maize :1 okra	656.1	9.7
1 maize : 2 okra	481.1	14.7
2 maize :1 okra	636.2	21.3
2 maize : 2 okra	503.6	15.0
Sole Maize	637.0	39.3
HSD (5%)	323.19	26.3

There were significant differences between the treatments in the number of striga plants associated with the maize. The number of striga plants in the sole maize was highest,

significantly greater than the number in the maize: okra (1:1) system which was the least. The number of striga plants in the other intercrop systems were however similar to that of the sole maize (Table 4.1).

4.2 EFFECT OF INTERCROPPING ARRANGEMENTS ON THE YIELD AND YIELD COMPONENTS OF MAIZE

From table (4.2), there were no significant differences between the treatments for number of cobs per plant, maize grain weight and maize grain yield. The number of cob per plant ranged between 1.5 and 1.7 ; maize grain weight between 0.10 and 0.24 kg/m^2; maize grain yield between 1030.0 and 2396.7 kg/ha.

Table 4.2: Effect of intercropping arrangements on the yield and yield components of maize

Crop Arrangements	Maize grain weight (Kg/m^2)	Grain yield (Kg/ha)	Number of cobs/plant
1 maize :1 okra	0.22	2190.0	1.6
1 maize : 2 okra	0.10	1030.0	1.5
2 maize :1 okra	0.16	1573.3	1.6
2 maize : 2 okra	0.15	1480.0	1.6
Sole Maize	0.24	2396.7	1.7
HSD (5%)	0.181	1810.6	0.56

4.3 EFFECT OF INTERCROPPING ARRANGEMENTS ON THE YIELD AND YIELD COMPONENTS OF OKRA

There were significant differences between the treatments for the total number of okra pods at harvest (Table 4.3). Okra in the maize: okra (1:2) intercrop arrangement produced 3.9 times more pods (56) than the okra in the 1:1 intercrop arrangement which produced the least number of pods (14.3).

Table 4.3: Effect of intercropping arrangements on the yield and yield components of okra

Crop Arrangements	Number of pods	Pod Length (cm)	Pod Girth (cm)	Pod Weight (g)	Malformed Pods (%)	Marketable Pod (%)
1:1	14.3	10.4	2.5	26.7	17.3	83.0
1:2	56.0	13.3	2.6	30.0	10.7	87.0
2:1	19.3	9.7	2.0	20.0	15.0	85.0
2:2	41.0	12.7	3. 1	30.0	15.7	84.3
Sole Okra	28.7	9.7	2.4	23.3	5.7	93.3
HSD (5%)	4.89	3.68	1.13	11.50	32.17	26.42

The total numbers of pods produced by the okra in the other intercrop arrangements were also significantly different from that of the okra in the 1:1 intercrop arrangement and from each other. Okra in the 2:2, sole and 2:1 arrangements produced 2.8 times, 2.0 times and 1.35 times, more okra, respectively, than the okra in the 1:1 arrangement. There were however no significant differences between the treatments for okra pod length, pod girth and pod weight. Okra pod length ranged between 9.7 cm and 13.3 cm; pod girth ranged between 2.0 cm and 3.1 cm and pod weight ranged between 20.0 g and 30.0 g. Similarly, there were also no significant differences between the treatments for percent malformed pods and marketable pod yield. The percent malformed pods ranged between 5.7% and 17.3% and percent marketable pods ranged between 83.0% and 93.3%.

4.4 POSTHARVEST QUALITY CHARACTERISTICS OF MAIZE AND OKRA AS AFFECTED BY INTERCROPPING ARRANGEMENTS

4.4.1 Proximate composition of maize grain

From table (4.4), there were significant differences between the treatments for grain moisture content (Table 4.4). Maize in the maize: okra (1:1) arrangement recorded the

highest moisture content, significantly different from 2:2 arrangement which recorded the least but similar to the 1:2 arrangement and sole maize. Maize from the 2:2 arrangement was however not different from that of the 2:1 arrangement.

Table 4.4: Proximate composition of maize grains as affected by the maize-okra intercrops arrangements

Crop Arrangements	Moisture Content (%)	Crude Protein Content (%)	Crude Fat Content (%)	Crude Fibre Content (%)	Ash Content (%)	Carbohydrate Content (%)
1:1	3.3	9.4	4.7	2.1	0.7	78.8
1:2	2.0	9.3	4.0	3.0	1.2	80.5
2:1	1.2	9.4	3.5	2.3	0.8	82.8
2:2	1.0	9.6	5.5	2.2	1.0	80.7
Sole Maize	1.3	11.0	4.3	2.1	1.5	79.5
LSD (1%)	2.09	7.57	4.60	2.33	1.12	9.29

There were however no significant differences between the treatments for crude protein content, crude fat content, crude fibre content, ash content and carbohydrate content. Crude protein content ranged between 9.4% and 3.02% ; fat content between 3.5% and 5.5% ; crude fibre content between 2.1% and 3.0% ; ash content between 0.7% and 1.5% and carbohydrate content between 78.8% and 82.8% (Table 4.4).

4.4.2 Mineral Composition of Okra Pod

There were significant differences between the treatments for calcium content of okra pods (Table 4.5). Okra in the maize: okra (2:1) system recorded the highest calcium content whereas okra in the maize: okra (2:2) system recorded the least, the difference being 62.5 %. There were however no significant differences between the treatments for okra content of potassium, magnesium, nitrogen, phosphorus, lead and copper.

Okra pod potassium content ranged between 0.80% and 0.91%. ; magnesium content between 0.22% and 0.28% ; nitrogen content between 1.48% and 1.76% ; phosphorus content between 0.26% and 0.32% ; lead content between 0.0007% and 0.041% and copper content between 0.02 and 0.05% (Table 4.5).

Table 4.5: Mineral composition of okra pod as affected by the maize-okra intercrops arrangements

Crop Arrangements	Calcium Content (%)	Potassium Content (%)	Magnesium Content (%)	Nitrogen Content (%)	Phosphorus Content (%)	Lead Content ($mgkg^{-1}$)	Copper Content ($mgkg^{-1}$)
1:1	0.11	0.81	0.27	1.51	0.29	0.035	0.03
1:2	0.09	0.91	0.28	1.48	0.31	0.034	0.03
2:1	0.13	0.87	0.22	1.51	0.26	0.017	0.05
2:2	0.08	0.83	0.26	1.53	0.32	0.041	0.02
Sole Okra	0.09	0.80	0.28	1.76	0.29	0.0007	0.04
HSD (1%)	0.035	0.172	0.094	0.885	0.136	0.0415	0.061

4.4.3 Chemical Composition of Okra Pod

There were no significant differences between the treatments for pH content, TSS, TTA and TTA: TSS. Okra pod pH content ranged between 4.83 and 5.00; TSS between 0.50 and 0.90% brix; TTA between 0.12% and 0.14% and TTA: TSS between 4.11 and 5.88 (Table 4.6).

Table 4.6. Chemical composition of okra pod as affected by the maize-okra intercrops arrangements

Crop Arrangements	pH Content	TTA content (%)	TSS Content (% Brix)	TTA:TSS
1:1	5.00	0.12	0.50	4.11
1:2	4.70	0.14	0.67	4.92
2:1	4.87	0.13	0.90	7.11
2:2	4.87	0.12	0.67	5.88
Sole Okra	4.83	0.13	0.70	5.59
HSD (1%)	0.665	0.050	0.747	7.089

4.5 CORRELATION RELATIONSHIPS AMONG SOME OF THE QUALITY PARAMETERS OF MAIZE AND OKRA

For maize, there was a strong negative and significant correlation among carbohydrates and crude protein (r = - 0.77). For okra, there was a strong negative and significant correlation among TTA and pH (r = -0.94). A moderate positive and significant correlation was found among pH and sugar: acid ratio (r = 0.53) also for okra (Table 4.7)

Table 4.7 Correlation relationships among some postharvest quality parameters of maize and okra

Correlation variables	Correlation coefficient (r)	Probability level
Carbohydrates and crude protein of maize	-0.77	0.000
pH and Sugar-Acid Ratio of okra	0.53	0.044
pH and TTA of okra	-0.94	0.000

4.6 ECONOMIC PROFITABILITY OF MAIZE-OKRA INTERCROPS.

The largest total revenue, profit and percent profit accrued was obtained under the maize-okra (2:2) intercrop arrangement (Table 4.8). The least total revenue of Gh₵7,583.33 was obtained under the sole okra system. However, the percentage of profit accrued was least under sole maize.

Table 4.8 Economic profitability of maize-okra intercrops arrangements

TREATMENT	TOTAL REVENUE (Gh₵/ha)	TOTAL COST OF PRODUCTION (Gh₵)	PROFIT (Gh₵)	% PROFIT ACCRUED
1 Maize:1 Okra	10,368.71	2,051.78	8,316.93	80.2
1 Maize:2 Okra	11,039.38	1,701.78	9,337.6	84.6
2 Maize:1 Okra	10,312.81	1,861.78	8,451.03	81.9
2 Maize:2 Okra	12,989.69	1,831.78	11,157.31	85.9
Sole Maize	10,075.07	2,111.78	7,963.29	79.0

Sole Okra	7,583.33	1,391.78	6,191.52	81.6

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 EFFECTS OF INTERCROPPING ON YIELDS OF MAIZE AND OKRA

In the present study, the inclusion of okra plants resulted in a significant reduction in the population of striga on the maize. The reduction in striga infestation was not related to any plant arrangement but the plant population. The extent of reduction by the inclusion of okra ranged from 75 % to 45.8 %. *Striga* is a parasitic weed that attacks cereal crops such as maize by siphoning water and nutrients for its growth, while above ground, the maize becomes stunted (Rodenburg *et al*., 2006; Atera *et al*., 2011) and grain yield is reduced (Khan *et al*., 2007). Maize grain yields lost to striga have been reported to range from 10 to 100% (Parkinson *et al.,* 1986; Lagoke *et al.,* 1991; Oikeh *et al.,* 2003). In the present study however, the striga population observed did not affect the growth and yield of the maize even under sole cropping conditions. This could probably be due to the fact that the striga populations were below the threshold which could cause reductions in the performance of the maize.

The comparable maize yields in the intercrops and the sole maize in the present study could be due to the non-competition between the okra and the maize such that the maize though in an intercropping system was still performing as it would under sole crop conditions. This non-competition between the okra and maize could be attributed to the different feeding zones exploited by the roots of the two crops, with okra being a deep rooted feeder as against the maize which is a shallow feeder. Vandermeer (1989), stated

that competition between different crop species is weaker when there are differentials in their zones of nutrient uptake.

5.2 INTERCROPPING ARRANGEMENT EFFECTS ON THE NUTRITIONAL QUALITY OF MAIZE GRAINS

In the present study, nutritional quality of the grains was not affected by the intercropping arrangements. This observation could be explained by the noncompetition that existed among the component plants as a result of the different horizons of nutrient uptake exploited by the roots. The nutritional quality of sole maize was similar to maize in the intercropping systems reported by Andersen *et al.*, (2007) and Fujita and Ofosu-budu, (1996) that most species differ with respect to the nutrient pool they tap from due to the difference in the below ground morphological features they possess which could be spatial or temporal. In similar studies conducted in Nigeria, Ujabadeniyi and Adebolu, (2005) and Enyisi, *et al.,* (2014) reported similar results with the present study for carbohydrate content, crude fibre and crude protein but not for ash content and fat content and attributed the differences to genetic or environmental factors.

5.3 MINERAL AND CHEMICAL COMPOSITION OF OKRA POD AS AFFECTED BY INTERCROPPING.

The present study revealed that, pod calcium content of okra was improved by the intercropping. This observation could be explained by the fact that, genetically, okra has a strong affinity for calcium (Crawley, 1997) and on the other hand, maize has poor affinity for calcium (Matilda *et al.,* 1993) and this explains the non-competitive ability of the maize plants for calcium in relation to the okra plants therefore its content in the pod was dependent on level of competition for the resource in the soil which could be

related to the prevailing plant density (Hauggard-Nielsen, *et al.,* 2001). This therefore explains the observed higher calcium content in the lower okra densities as compared to the higher densities. The low calcium levels in the higher okra densities could be due to the strong intraspecific competition for calcium among the okra plants in the high densities. Rizzi and Abruzzese, (1990) indicated that calcium is required for fruit formation and filling and is considered as one of the most important minerals determining the quality of fruits. This therefore implies that the pod quality of okra was improved by intercropping at okra at low densities with maize. This is the first report of okra pod quality improvement with maize intercropping.

For the other minerals, however there were no differences between the intercropping arrangements treatments and could be due to the non-competition for nutrients between the maize and okra as a result of the differential root feeding ones. Vandermeer, (1989) stated that competition between different crop species is weaker when there are differentials in their zones of nutrient uptake. Similarly, Andersen *et al.,* (2007) and Fujita and Ofosu-budu, (1996) reported that most species differ with respect to the nutrient pool they tap from due to the difference in the below ground morphological features they possess which could be spatial or temporal.

In this present study, several strong negative correlations were found among the chemical quality parameters of okra. This suggests that the acidity level of okra pods could be determined by the knowledge of its pH (Dadzie and Orchard, 1997) which has implications on the maturity status of the pods. Similarly, from the negative correlation among carbohydrate content and protein content, the protein quality of the pods could be assumed to be high if the pods are less matured and hence edible than when fully

mature with a high carbohydrate content. On the other hand, the positive correlation among pH and the sugar: acid ratio implies that as the pod pH increases towards maturity, the sweetness and hence edibility of the pod becomes pronounced and as such a knowledge of the pH of the pod could provide information on the level of edibility of the pods.

Generally, this present study has demonstrated that intercropping maize with okra in various plant arrangements did not affect the postharvest quality of the maize whiles improving the pod quality of the okra. Consequently, the two crops can be intercropped without the loss of any nutritional or chemical quality of either component crop in the system.

5.4 ECONOMIC PROFITABILITY OF INTERCROPPING SYSTEMS.

All the intercropping arrangements, in the present study, recorded high economic profitability such that 80-86% of the total revenue accrued was retained as profit. This finding is similar with Sarker *et al*. (2014) who reported that, intercropping maize with short duration vegetables may be profitable than sole maize and that all the intercrop combinations are economically viable than sole cropping.

In the present study, the intercrop arrangements with higher okra densities recorded higher percentages of profit accrued as compared to the intercrop arrangements with lower okra densities. This suggests that okra cultivation, as observed in the present study, is very cost effective and highly profitable and therefore its increased inclusion in an intercropping system is most likely to ensure high economic benefits. The high profitability of okra was again demonstrated in the present study, whereby the sole okra system out-performed the sole maize and maize: okra (1:1) systems in terms of

percentage of profits accrued. This might probably be due to the greater contribution of okra in terms of yield and low production cost resulting in the high percent of profit accrued. Conversely, the sole maize system produced the highest cost of production with a resultant least percent of profit accrued. Similar findings were reported by

Alabi and Esobhawan, (2006) in a relative economic value of maize-okra intercrops. Although the percent profit accrued of the sole okra was greater than that of the maize-okra (1:1) intercrop system, it is important to note that farmers practice multiple cropping not only for profit maximization but also for income stability. Intercropping maize and okra is highly profitable, with the level of profitability increasing as the population of okra in the intercrop system was increased.

CHAPTER SIX
6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions could be drawn from the series of experiments undertaken in this study. Doubling the population of okra without a corresponding increase in maize density resulted in a significant reduction in the population of striga on the maize even though the striga population observed did not affect the growth and yield of the maize even under sole cropping conditions.

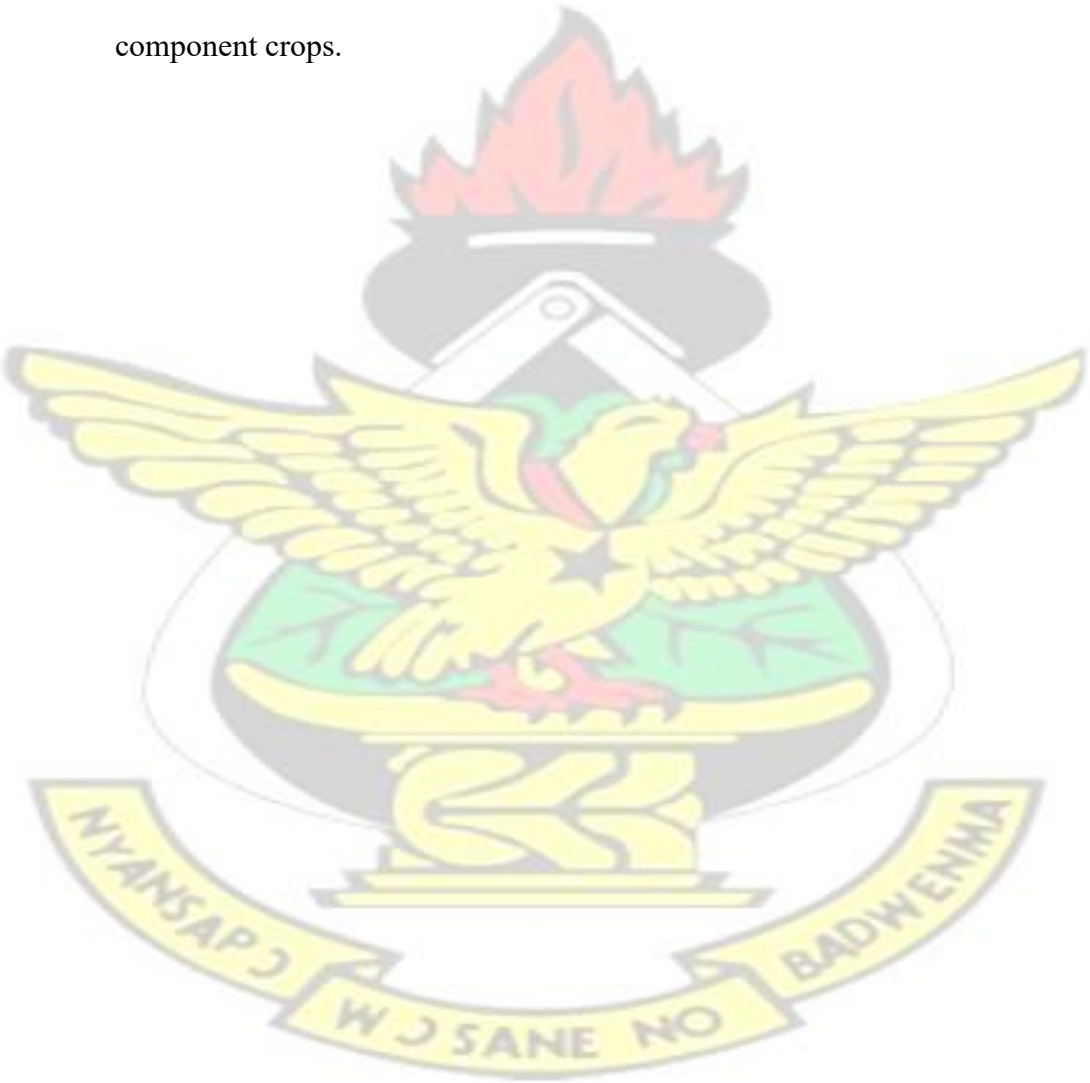
Pod calcium content was improved by the intercropping but at low okra densities within the intercropping system. For the other minerals (N, P, K, Cu, Mg, Mn, Zn, and Pb), however there were no differences between the intercropping arrangements treatments. For maize, there was a strong negative and significant correlation between carbohydrates and crude protein. For okra, there was a strong negative and significant correlation between TTA and pH and a moderate positive and significant correlation between pH and Sugar: Acid ratio.

Generally, this study has demonstrated that intercropping maize with okra in various plant arrangements did not affect the postharvest quality of the maize whiles improving the pod quality of the okra and hence the two crops can be intercropped without the loss of any nutritional or chemical quality of either component crop in the system.

Intercropping maize and okra is highly profitable, with the level of profitability increasing as the population of okra in the intercrop system was increased. In addition, the cost of producing maize was high and eroded the percentage of profit accrued to the production of the crop.

6.2 Recommendations

1. Other vegetable-based intercropping systems should be studied to provide more information for farmers use.
2. The effect of other plant arrangements should be studied to determine their influence on postharvest qualities of other vegetable crops.
3. The present study should be extended to other agro-ecological zones to ascertain the environmental effects on the postharvest quality characteristics of the component crops.



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APPENDICES

ANALYSIS OF VARIANCE

MAIZE 1. ANALYSIS OF VARIANCE TABLE FOR GRAIN YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	12573503.85	6286751.93	15.25	0.0019
treatment	4	3699972.25	924993.06	2.24	0.1537

2. ANALYSIS OF VARIANCE TABLE FOR GRAIN WEIGHT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	5.51755773	2.75877887	16.02	0.0016
treatment	4	2.52719107	0.63179777	3.67	0.0556

3. ANALYSIS OF VARIANCE TABLE FOR LEAF AREA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	70927.62533	35463.81267	2.69	0.1277
Treatment	4	83331.53067	20832.88267	1.58	0.2690

4.ANALYSIS OF VARIANCE TABLE FOR STRIGA COUNT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	458.800000	229.400000	2.63	0.1325
Treatment	4	1607.333333	401.833333	4.61	0.0318

5. ANALYSIS OF VARIANCE TABLE FOR MEAN NUMBER OF COBS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.49401333	0.24700667	6.19	0.0238
Treatment	4	0.10530667	0.02632667	0.66	0.6372

6. ANALYSIS OF VARIANCE TABLE FOR MEAN COB GIRTH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	4.62868000	2.31434000	7.20	0.0163
Treatment	4	3.62982667	0.90745667	2.82	0.0989

7. ANALYSIS OF VARIANCE TABLE FOR MEAN COB WEIGHT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.02678760	0.01339380	14.97	0.0020
Treatment	4	0.00881093	0.00220273	2.46	0.1295

OKRA 8 ANALYSIS OF VARIANCE TABLE FOR POD YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	68862.876	34431.438	0.05	0.9492
Treatment	4	3857995.874	964498.968	1.47	0.2977

9. ANALYSIS OF VARIANCE TABLE FOR TOTAL POD WEIGHT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.14849333	0.07424667	0.18	0.8378
Treatment	4	4.54876000	1.13719000	2.77	0.1026

10 ANALYSIS OF VARIANCE TABLE FOR TOTAL NUMBER OF PODS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	292.133333	146.066667	0.62	0.5624
treatment	4	3421.733333	855.433333	3.62	0.0572

11 ANALYSIS OF VARIANCE TABLE FOR MEAN NUMBER OF PODS

Source	DF	Type III SS	Mean Square	F	Pr > F Value
Rep	2	0.45733333	0.22866667	0.52	0.6126
treatment	4	1.52666667	0.38166667	0.87	0.5217

12. ANALYSIS OF VARIANCE TABLE FOR MEAN POD LENGTH

Source	DF	Type III SS	Mean Square	F	Pr > F Value
Rep	2	3.00268000	1.50134000	0.88	0.4515
treatment	4	35.92869333	8.98217333	5.26	0.0224

13. ANALYSIS OF VARIANCE TABLE FOR MEAN POD GIRTH

Source	DF	Type III	Mean Square	F Value	Pr > F

SS

Rep 2 0.34337333 0.17168667 1.07 0.3877 **treatment** 4 1.77702667 0.44425667 2.77 0.1029

14. ANALYSIS OF VARIANCE TABLE FOR MEAN POD WEIGHT

Source DF Type III SS Mean Square F Value Pr > F Rep 2 0.0000000 0.0000000 0.00 1.0000 **treatment** 4 226.6666667 56.6666667 3.40 0.0662

15 ANALYSIS OF VARIANCE TABLE FOR PERCENTAGE OF MALFORMED FRUITS

Source DF Type III SS Mean Square F Value Pr > F Rep 2 426.5333333 213.2666667 1.63 0.2541

Treatment	4	267.0666667	66.7666667	0.51	0.7297

16 PERCENTAGES OF MARKETABLE FRUITS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	1484.933333	742.466667	8.43	0.0107
Treatment	4	198.400000	49.600000	0.56	0.6964

POSTHARVEST PARAMETERS

17 ANALYSIS OF VARIANCE TABLE FOR TOTAL SOLUBLE SOLIDS

Source	DF	SS	MS	F	P
Treatment	4	1.077E-03	2.693E-04	0.73	0.5897
Error	10	3.673E-03	3.673E-04		
Total	14	4.750E-03			

18. ANALYSIS OF VARIANCE TABLE FOR TOTAL TITRABLE ACIDITY

Source	DF	SS	MS	F	P
Treatment	4	1.420E-05	3.550E-06	0.40	0.8022
Error	10	8.802E-05	8.802E-06		
Total	14	1.022E-04			

19. ANALYSIS OF VARIANCE TABLE FOR TOTAL SOLUBLE SOLIDS: TOTAL TITRATABLE ACIDITY

Source	DF	SS	MS	F	P
Treatment	4	0.00830	2.074E-03	0.51	0.7310

Error 10 0.04079 4.079E-03
Total 14 0.04908

20. ANALYSIS OF VARIANCE TABLE FOR ASH CONTENT

Source	DF	SS	MS	F	P
Treatment	4	4.933E-04	1.233E-04	3.08	0.0677
Error	10	4.000E-04	4.000E-05		
Total	14	8.933E-04			

21. ANALYSIS OF VARIANCE TABLE FOR DRY SAMPLE WEIGHT

Source	DF	SS	MS	F	P
Treatment	4	4.373E-03	1.093E-03	4.21	0.0298
Error	10	2.600E-03	2.600E-04		
Total	14	6.973E-03			

22. ANALYSIS OF VARIANCE TABLE FOR FAT CONTENT

Source	DF	SS	MS	F	P
Treatment	4	2.707E-03	6.767E-04	1.00	0.4493
Error	10	6.733E-03	6.733E-04		
Total	14	9.440E-03			

23. ANALYSIS OF VARIANCE TABLE FOR pH

Source	DF	SS	MS	F	P
Treatment	4	0.13733	0.03433	0.52	0.7233
Error	10	0.66000	0.06600		
Total	14	0.79733			

24 ANALYSIS OF VARIANCE TABLE FOR CARBOHYDRATES

Source	DF	SS	MS	F	P
Treatment	4	27.0679	6.76697	0.99	0.4577
Error	10	68.5924	6.85924		
Total	14	95.6603			

50 ANALYSIS OF VARIANCE TABLE FOR CRUDE FIBRE

Source	DF	SS	MS	F	P
Treatment	4	1. 80487	0.45122	1.04	0.4320
Error	10	4.32273	0.43227		
Total	14	6.12760			

25 ANALYSIS OF VARIANCE TABLE FOR CRUDE PROTEIN

Source	DF	SS	MS	F	P
Treatment	4	6.1077	1.52692	0.33	0.8484
Error	10	45.6057	4.56057		
Total	14	51.7134			

26. ANALYSIS OF VARIANCE TABLE FOR NITROGEN

Source	DF	SS	MS	F	P
Treatment	4	0.15476	0.03869	0.33	0.8510
Error	10	1.16893	0.11689		
Total	14	1.32369			

27 ANALYSIS OF VARIANCE TABLE FOR CALCIUM

Source	DF	SS	MS	F	P
Treatment	4	0.00491	0.00123	6.57	0.0073
Error	10	0.00187	0.00019		
Total	14	0.00677			

28 ANALYSIS OF VARIANCE TABLE FOR COPPER

Source	DF	SS	MS	F	P
Treatment	4	0.00141	3.522E-04	0.62	0.6574
Error	10	0.00566	5.663E-04		
Total	14	0.00707			

29 ANALYSIS OF VARIANCE TABLE FOR POTASSIUM

Source	DF	SS	MS	F	P
Treatment	4	0.02233	0.00558	1.26	0.3466
Error	10	0.04420	0.00442		
Total	14	0.06653			

30 ANALYSIS OF VARIANCE TABLE FOR MAGNESIUM

Source	DF	SS	MS	F	P
Treatment	4	0.00603	0.00151	1.15	0.3870
Error	10	0.01307	0.00131		
Total	14	0.01909			

31 ANALYSIS OF VARIANCE TABLE FOR PHOSPHORUS

Source	DF	SS	MS	F	P
Treatment	4	0.00684	0.00171	0.62	0.6607
Error	10	0.02773	0.00277		
Total	14	0.03457			

32 ANALYSIS OF VARIANCE TABLE FOR LEAD

Source	DF	SS	MS	F	P
Treatment	4	0.00237	5.919E-04	2.31	0.1294
Error	10	0.00257	2.566E-04		
Total	14	0.00493			

33 ANALYSIS OF VARIANCE TABLE FOR ZINC

Source	DF	SS	MS	F	P
Treatment	4	3.600E-06	9.000E-07	0.04	0.9962
Error	10	2.180E-04	2.180E-05		
Total	14	2.216E-04			

34 BASIC COST OF PRODUCTION FOR THE EXPERIMENTAL AREA (576 m^2)

ITEM/ OPERATION	UNIT COST (GHC)	TOTAL COST(GHC)
PLOUGHING	30.00	30.00
HARROWING	25.00	25.00
SOWING	30.00	30.00
FIRST WEEDING	40.00	40.00
FERTILIZER (NPK)	28.80	28.80
FERTILIZER APPLICATION	30.00	30.00
FERTILIZER (SULPHATE OF AMMONIA)	12.24	12.24

FERTILIZER APPLICATION	30.00	30.00
SECOND WEEDING	40.00	40.00
HARVESTING(MAIZE)	30.00	30.00
HARVESTING(OKRA)	75.00	75.00
DEHUSKING	30.00	30.00
SHELLING	30.00	30.00
OKRA SEEDS	30.00	30.00
MAIZE SEEDS	30.00	30.00
TOTAL		**GHC 481.04**

COST OF DRYING OF MAIZE: GHC 10.00 PER 100KG BAG

1:1 = 660

1:2 = 310

2:1 = 470

2:2 = 440

Sole maize = 720