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EFFECTS OF INTERCROPPING AND CROPPING SYSTEMS ON THE POSTHARVEST QUALITY OF MAIZE AND ROSELLE.

BY

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

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DECLARATION

I, Naaba Anecham Jonathan, do herein declare that I personally undertook this project work and that it has not been produced anywhere for award of a degree except other people`s works cited which have been dully acknowledged.

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DEDICATION

I dedicate this dissertation to God Almighty Father for His mercy guidance throughout the work. Also, my wife – Miss Esther Wepalam, my mother, Director of IITA Dr. Alarbi Asamoah and staff, Theodore Eyram Avukpor, Mohammed Abdul Kadir, Iddrisu Mohammed Bashiru, and my children (Naaba Elisha Atogeweh, Perpetua Kalao, and Felicity Akiwelie).

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ABSTRACT

Hibiscus cannabinus L., commonly called Roselle, is an important vegetable among subsistence farming households especially in most developing countries. Never the less, the productivity of maize and Roselle under intercropping arrangements is not well known. The research work on effects of intercropping and cropping systems on post harvest quality of maize and Roselle was done to determine the agronomic performance of the intercrop systems, post- harvest quality and also profitability of the intercrop arrangements. The study showed that sole maize and sole Roselle produced the highest yields per hectare compared with the intercrop systems. Within the intercrop systems, 2:2 intercrop arrangements also produced the highest grain yield of maize and Roselle leaf yield (1685.4kg and 16981.3kg/ha respectively). The least yield was produced by 1:2 of both maize and Roselle. However, the combine effect of intercropping maize and Roselle in two rows of maize and two rows of Roselle produced the highest yield and accrued profits. The least was produced by 1:2 intercrop arrangements. All the intercrop system or arrangements save significant proportion of land that otherwise will be needed by a mono cropping pattern to yield the same results. However, one row of maize and two rows of Roselle (1:2) arrangements do not save land and therefore it is not economically prudent to embark on 1:2 arrangements of maize and Roselle in the intercrop system. Monitoring of Roselle fresh leaf shelf life showed that by day two, Roselle leaves shrivel and takes three days for the leaves to completely change colour from the original green. The study also revealed that Ca, Zn, Pb, Cu, N, P, PH, TSS, TTA percentages in Roselle leaves are independent of any of the plant arrangements. However, the intercrop system has effects on Mg concentration in Roselle leaves. Two rows of maize and two rows of Roselle (2:2) arrangements contain the least percentage of Mg whiles one row of maize and one row of Roselle (1:1) arrangement had the highest Mg levels accumulated in the leaves.

The percentage concentration of crude protein and carbohydrates are very high in Roselle leaves within the intercrop arrangement than sole cropping. However, increasing the number of rows of Roselle and reducing the number of rows of maize reduces the crude fat concentration in Roselle leaves but reducing the number of rows of Roselle and increasing the number of rows of maize results in increase in crude fibre content in the leaves of Roselle. These findings will be very useful especially to farmers.

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CHAPTER ONE

1.0 INTRODUCTION

Intercropping refers to the growing of more than one crop in a particular field at the same time to enhance their interaction in order to improve productivity so as to avoid over dependence on one crop (Wolfswinkel, 2006). The main purpose of intercropping is to provide optimun harvest within a given parcel of land taking into consideration efficient use of resources that would not be possible under sole cropping (Ouma *et al.*, 2010). According to Ouma *et al*. (2010), various intercrop patterns have been identified to include strip intercropping, row intercropping, mixed intercropping and relay intercropping which refers to planting a second crop amongst the first growing crop which is in its reproductive stage but before harvesting.

The benefits of intercropping systems are enormous. According to Pawan *et al*. (2012) intercropping of compatible plants encourages biodiversity. Biodiversity in the intercrop system means more benefits resulting in risk spreading and limiting out breaks of crop pest. Intercropping system also results in improved and diversified crop yield, increased available fodder and organic manure, enhanced soil fertility, soil cover, pest and disease control, weed control, physical support in the case of maize and climbing beans, and micro climate amelioration (Wolfswinkel, 2006). Intercropping improves food and income security and ultimately contribute towards reducing poverty and starvation among households.

Maize (*Zea mays*) belongs to Poaceae family and the tribe Andropogoneae and originates from south-eastern Mexico. Maize is described as an annual crop as it grows to complete its life cycle within one season and it is grown almost everywhere in the world (Winter, 2009).There are about fifty (50) varieties of maize that exist with many colours ranging from e.g. black in the range o white to yellow (http://www.iita.org/maize, 2014). Maize is a cereal crop of immense importance to the economy of every nation. FAO, (2009) reported that the largest producer of maize is the United States representing 42% and the production of maize in the world is about 785 million tons. The report further stated that 6.5% of the maize is produced in Africa with Nigeria being the largest producer - nearly 8 million tons. Second to Nigeria is South Africa. Indeed, 28% of maize required by Africa is imported. The production of maize is mainly rain fed in Africa and erratic rain fall can cause famines, food insecurity, family conflicts, slow down national development of a country especially during droughts (http://www.iita.org/maize, 2014).

The most widely cereal crop cultivated and consumed in Ghana is Maize (FASDEP II, 2007).

The production of maize is 50%-60% of the total volume of cereals produced in the country (FASDEP II, 2007). The production of maize ranks second to cocoa. Other crops such as cassava, yam, oil palm, groundnut, plantain, sorghum, cocoyam, cowpea, and other pulses come after maize (http//www.dtma.cimmyt.org, 2014).

The production of maize in Ghana has not changed with regards to yield and hectares cultivated due partly to the dependence of low adoption of improved farming practices. In Ghana, the total hectares of maize cultivated is about one million hectares (1000000ha) and the average yield per hectare is 1.74 metric tons (MT) per hectare and the total volume of maize produced in the country is 1.65 million MT per annum (http://www.iita.org/maize, 2014).

Maize grains are said to be rich in nutrients. According to IITA, (2009) report, the nutritional composition of maize includes carbohydrates for energy, minerals, vitamins (Vit. A, C, and E) and 9% protein. Dietary fibre and calories are also present in maize. Ensminger, (1994) reported that maize provides a good source of starch. The popular use of corn starch (maize flour) is for domestic cooking and other food products. Cooking oil and gluten are also obtained from Maize.

The report further stated that maize starch can be enzymatically treated and hydrolyzed to produce syrups, especially high-fructose corn syrup, and a sweetener. Alcohol - a traditional beverage is also obtained from maize grains.

According to Boateng *et al*, (1990) revenue obtained from crop sales is about 16.8% in Ghana and the revenues obtained by ultra-poor people from crop sales is 8.5%. Indeed, maize production and marketing creates job opportunities for the youth especially women. Its job opportunities are in the areas of production, processing, transportation, storage and marketing. It is one of the major areas of research partly due to its immense contribution to the Gross Domestic products of Ghana (FASDEP II, 2007).

Roselle (*Hibiscus cannabinus L.*) is a prominent vegetable crop grown in the tropics. Roselle crop belongs to the family Malvaceae (Bahaeldeen, 2012). Roselle is mainly produced by small holder farmers in localised growing conditions, depending on rainfall and natural soil fertility without using inorganic chemicals. A small portion of the crop produced is used locally whiles the larger portion of it is exported to China (Ahmed *et al.*, 2012). Roselle popularly called kenaf is commonly cultivated locally in a mixture with cereals and legumes especially in the Guinea savannah ecological zones. However, the intercrop systems have not been well studied (Babatunde, 2000).

The economic importance of Roselle cannot be over emphasized. Vegetative parts of Roselle (young shoots, leaves and calyxes) are used to prepare vegetable soup and also as vegetable sauce. Dried calyxes of Roselle are also used to prepare sugaring colour tea. Beverages such as syrup, jams and jellies are prepared from the calyx. Roselle succulent leaves and shoots are consumed raw after they are well washed. The calyces of Roselle are also a good source of fodder for livestock feeding in Africa. The seed of Roselle contains oil which is used in soap making and cosmetic

(Mehdi et al., 2013). In addition, oil extracted from the seed is used for making paint and for domestic food preparation. Again, Roselle seeds are used to prepare various dices in some villages (Bahaeldeen, 2012). The calyxes, leaves and young shoots have been known to have high medicinal and nutritional value (Bahaeldeen, 2012). Roselle provides income to the rural poor and therefore contributes to reducing food and income insecurity. Pau (2002) reported that Roselle is of increases the production of nitric oxide in the body and reduces blood pressure through oxidizing lipids.

1.1 PROBLEM STATEMENT

In Ghana, the majority of the people are food insecure, with the highest densities of such people living in the three northern regions (WFP, 2010). Ghana is said to have 1.2 million people suffering from food insecurity. Upper west is the most suffering with about 34% of the populace in the region engulfed in food insecurity. Upper east ranks second with about 15% of the populace suffering whiles 10% of the population in Northern region are not left out. This approximately amounts to 453,000 people (WFP, 2009).

As part of the research work done by Africa Rising Project under the auspices of International Institute of Tropical Agriculture (IITA), the 2013 technical report revealed that agriculture is rain fed and predominant by small scale crop farmers in all the communities in Northern Ghana. The dominant cultivated cereal crop in Northern Ghana is maize, sorghum, rice and millet. The cereal crops are usually cultivated as a single crop in pure stand and sometimes mixed cropped with grain legumes and vegetables. Vegetables (Roselle, pepper and okra) in particular are considered as women"s crop and are therefore usually planted as a boundary crop at the periphery of farms (Hoeschle-Zeledon, 2013). Crop yields are therefore low as a result of erratic rainfall, poor agronomic practices (particularly failing to achieve required plant density), low soil fertility, drought, poor access to improved seeds, diseases and pests (*Striga hermonthica*). Inadequate knowledge in intercropping options and low technological drive highly contribute to low yields (Hoeschle-Zeledon, 2013). This problem is also highlighted by Quaye (2008) who added that agricultural land is becoming scarce due to the burgeoning population. There is therefore high competing demand for land for crop cultivation and other infrastructural development.

Whiles crop yields keep dwindling, huge quantities of grains and vegetables go down the drain as post-harvest losses each year increasing the hunger gap situation in sub-Sahara Africa. Hence farm inputs such as fertilizers, water, labour and other resources being wasted and reducing the profit margin of crop production (Niculescu Et al., 2013). The causes of postharvest losses are enormous. These include; inappropriate harvesting methods, handling procedures, drying techniques, filth or contamination, attacks by rodents, birds and other animals and pests such as insect damage and infestation by food-borne pathogens (World Bank/NRI/FAO, 2011). The post-harvest losses of fruits, vegetables, roots and tubers are very high and ranges between 2050%. The losses in cereals and legumes is moderately high ranging from 20% - 30%. This is due to poor production and harvesting techniques and partly due to poor transportation and lack of adequate storage and packaging facilities. This makes most farmers to sell their produce in the open markets immediately after harvesting at low prices but only to re-buy them at a higher cost during the lean season for consumption. (FASDEP II, 2007).

The nutritional status of most farm households in the Northern region is generally low, particularly for pregnant women, breast feeding mothers and young children and the old aged people as a result of low yields and high postharvest losses in relation to balancing their diet (Hoeschle-Zeledon, 2013). The situation is worst during the lean season when there is scarcity of food. Profit margins are also low as crop population densities are not met coupled with over reliance on sole cropping which predispose farmers to investment losses. Based on the existing production challenges, it is most appropriate to redefine and design cropping technologies that are required to combat low yields and postharvest quality problems using intercropping innovation.

1.2 JUSTIFICATION

Food security is a treat in the African environment. According to GRACE Communications Foundation (2014), food security is described as the existence of good quality food which meets the needs of all people at all the times for a better life. The food must necessary be available, accessible and able to be utilised. Agriculture therefore forms the bases for tackling and meeting households‟ food security needs. In Northern Ghana, the majority of households (88%) solely depends on crop cultivation as their main livelihood activity and about 95% of the households harvest one or more crops annually (WFP, 2012 and FASDEP II, 2007).

In the Northern region, the most widely cultivated crop is maize which is commonly consumed. The staple food in Northern Ghana is the Tuozaafi (TZ) commonly eaten with vegetable sauce. Vegetables, particularly Roselle, have multipurpose uses which includes its medicinal importance. Yields of vegetables, cereals and legumes are however low and post-harvest losses are high making households prone to severe hunger and starvation. It is particularly difficult to store fresh vegetables for use during the dry and lean seasons when hunger is severe. The nutritional contents of dry vegetables remains uncertain as postharvest handling have a role to play (Hoeschle-Zeledon, 2013).

As yields of crops are low and nutritional demands of families are threatened, farmers have over the years adopted copying strategies during the lean season. Some household members migrate to southern Ghana in search of jobs („‟Kayayo‟‟‟). They also migrate to solicit support from relatives and friends outside the regions. Food insecurity can result in the sale of livestock and other valuable assets. This can also lead to reduction in the quantity of food intake (Quaye, 2008). Overcoming malnutrition requires a combination of interventions in different areas that guarantee the availability of and access to quality food for growth and development (FAO, 2013). Economic growth is supported with innovations. Investing in research and development especially in agriculture is one sure way that will speed up economic growth (FAO, 2014).

Intercropping systems can therefore be used to avoid total losses of single cropping pattern in order to ensuring food security (Wolfswinkel, 2006). The intercropping systems have to be well studied to provide the best intercrop arrangements for optimal yield and good post harvest qualities (Babatunde, 2000).

It is therefore envisaged that maize and Roselle (kenaf) intercropping systems will give various intercropping options that will address yields, postharvest qualities and profitability thereby reducing hunger and malnutrition of rural poor in Northern Region.

1.4 MAIN OBJECTIVE

The main objective of the study was to ascertain the effect of intercropping and cropping systems on postharvest quality of maize and Roselle.

1.4.1 Specific Objectives

- To determine the effects of different plant arrangement on agronomic performance of maize and Roselle inter-crops.
- To determine the effect of plant arrangement on the postharvest quality of maize and Roselle intercrop.
- To carry out cost-benefit analysis on various cropping systems.

CHAPTER TWO

2.0 LITERATURE REVIEW

INTRODUCTION

This literature review covers a wide range of arena stemming from description and importance of intercropping, cultural practices, agronomic issues to post-harvest quality which embodies shelf life, nutritional composition of maize and vegetables.

2. 1 DESCRIPTION OF INTERCROPPING SYSTEM

The challenges with agriculture production include maintenance of soil fertility and water management. This can be addressed by employing intercropping systems as one of the options to improving soil and water conservation in order to increase crop yields. Intercropping involves two or more crops grown on the same piece of farm land. It involves the practical demonstration of ecological principles for improved diversity, crop interaction and other natural regulation mechanisms. The motive behind intercropping has to do with component crops complimentarily and risk spreading (Pawan *et al*, 2012).

A wide range of crops can be used for intercropping. These include cereals (maize, sorghum, rice, and millet), legumes (cowpea, soya beans, pea nuts, sesame) and vegetables (Roselle, amaranthus, tomatoes, pepper, and okra). Many intercropping systems between maize and vegetables have been studied. However, the intercropping of maize and Roselle have not been well studied (Babatunde, 2000).

2. 1.1 Principles of Intercropping

According to Chandrasekaran *et al*. (2010), there are various principles of intercropping. These include;

i. The component crops should be complimentary to each other.

ii. The main crop should have longer duration and slow growing habits allow the component crop to grow fast. iii. The component crops in the intercrop system should require similar agronomic practices.

iv. Crops of different families can be intercropped together especially erect and creeping crops.

v. Crops with the ability to resist erosion should be intercropped with those less able to resist erosion.

vi. It is appropriate to have component crops with different rooting pattern and depth of rooting.

2. 1.2 Types of intercropping

Various publications identified various types of intercropping to be practised across the globe. According to Ouma *et al*. (2010 and Pawan *et al*. (2012), there are four main spatial arrangements of intercropping. These include;

1. **Strip Intercropping-** this intercropping system refers to the planting of more than one crop in strips and well-spaced to allow farm operations, and close enough for component crops interactions.

2. **Row Intercropping-** the system entails the cultivation /growing of more than one crop in a well pronounced rows (http://www.infonet-biovision.org/print/ct/253/soilFertilityManagement, 2012).

3. **Mixed Intercropping-** in this case more than one crop are planted together in no specific arrangement (http://www.infonet-biovision.org/print/ct/253/soilFertilityManagement, 2012).

4. **Relay Intercropping –** with this intercrop system, among the first is grown a second crop at the stage where the first crop is almost at reproductive level (Ouma *et al.*, 2010).

2.2 IMPORTANCE OF MAIZE AND ROSELLE INTERCROP

The advantages/ importance of intercropping cannot be over emphasized. In the cereals (maize) and vegetables especially maize and roselle intercrop includes the following;

2.2.1 Biodiversity and stability

Growing two or crops together help to improve the biodiversity of the farm. The more diversity of a farm implies more food, stability, resulting in risk spreading (Pawan, 2012).

2.2.2 Increased yield

When two or more crops with different levels of nutrients and water uptake are planted together it results in efficient use of nutrients and water thereby the combined effects of yields of the intercrop can be higher than the yield of sole crop (Pawan *et al*, 2012 and Chandrasekaran *et al*, 2010).

2.2.3 Soil fertility Maintenance

One important benefits of intercropping is the improvement and maintenance of soil fertility. This is achieved by growing legumes with cereals/tubers in association with vegetables. Deep or shallow rooted plants will not ideal in the mixture as they take nutrients from the same level. Pigeon pea are known to take up nutrients from deeper soil layer, there by recycle nutrients leached from the surface. Legumes also grow well in low phosphate. After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop (Pawan *et al*., 2012).

2.2.4 Intercrop as Insurance against Crop Failure

Intercropping is one of the surest ways of ensuring food security among farm families in developing countries due to its stability compared with sole cropping. Literature shows that for a particular „disaster" level quoted, sole pigeon pea crop would fail one year in five, sole sorghum crop would fail one year in eight, but intercropping would fail only one year in thirty six. Intercropping is said to be more stable due to the partial restoration of diversity that is lost under mono cropping (Lithourgidis *et al.*, 2011). Intercropping provides high level of assurance against crop failure, especially extreme weather conditions. Greater insurance is financial stability for farmers, making the system particularly suitable for labour-intensive small farms (Lithourgidis *et al.*, 2011 and Chandrasekaran *et al.*, 2010).

2.2.5 Improvement of Forage Quality

The value of fodder for livestock in quantity and quality improves when intercropping system such maize – vegetables (roselle), cereals - legumes, legumes – vegetables are practiced (Chandrasekaran *et al*, 2010). Most patterns of intercropping maize with either vegetables or legumes produce more forage than sole crops.

2.2.6 Lodging Resistance

Some crops such as maize are susceptible to lodging during heavy rain fall and storm. Component crops such as Roselle in an intercropping system can provide mechanical support to such susceptible ones. Lodging is commonly observed in cereals and some vegetables and this can frequently reduce plant growth severely. Some of the damages are often caused by disease infections and mechanical damage. Lodging can reduce efficiency of light interception, therefore intercropping can help prevent lodging through mechanical support to weaker plants (Lithourgidis *et al*, 2011).

a) When intercropping system is practiced, it creates job opportunities and offers better utilization of labourers, machine and power throughout the year (Chandrasekaran et al, 2010).

b) Intercropping inhibits the spread of diseases and pests since it is not all crops involved are susceptible to the same extent of problems (Pawan, 2012).

c) Intercropping is able to reduce specific weeds like Bermuda grass, Cyprus (sedges) and *Trianthema portulacastrum*, *Striga hermontica* (witch weed).

2.2.7 Microclimate Amelioration

Intercropping is able to conserve soil and water temperature and creates micro climate for other living organisms. This can very useful in decomposition of organic matter and soil fertility enhancement.

2.2.8 Risk spreading

The benefits of maize and vegetables (Roselle) intercrop cannot be over emphasized. These include diversified food and income sources, nutritional balance, risk spreading, increase yields, medicinal value especially from Roselle. One serious demerit of intercropping is the practical management of the system especially where it involves a high degree of mechanization.

Machinery used for sowing, weeding, fertilizing, and harvesting are made for big uniform fields. Also, it becomes a challenge when the component crops have different agronomic requirements. (Lithourgidis *et al*, 2011).

2.3 CULTURAL PRACTICES FOR MAIZE AND ROSELLE

2.3.1 Land preparation

This is usually done during the first rains in May/June. Deep plough is employed for deep rooted crops whiles shallow ploughing (ridges) is done for shallow rooted crops such as maize, Roselle and other vegetables (Pawan *et al*, 2012).

2.3.2 Sowing

Sowing follows after land preparation. Usually, direct seeding is done for most of the cereals such as maize, millet, sorghum. Maize is planted at a distance 80cm by 40cm and two seeds per planting hole. Vegetables are usually raised in a nursery and later transplanted on to the main field. However, Roselle and okra are planted directly on the field with the planting space 6ocm by 40cm (Wolswinkel, 2006). In order to get the required seed rate for optimum plant density, one will have to make adjustments to the planting distance of the component crops

(http://www.attra.org/attra-pub/intercrop.html) Accessed on Tue, 1 Feb 2000 17:09:13 -0600. Overcrowding can lead to low competition for light, space, nutrients, and water hence low yield. Refilling and thinning are required to maintain the required plant population (Chandrasekaran *et al*, 2010).

2.3.3 Weeds Control

Weeds are obnoxious plants that compete with field crops for water, space, light and nutrients. Weeds can cause extensive damage to field crops for about 29.5 – 74.0% loss of maize yield. Common among the known weeds are *Striga hermontica*, *Cynodon dactylon*, nut grass (*Cyperus rotundus*). In an intercropping system, weeds are commonly easily controlled. The methods of weed control can be done using simple tools such as hand hoe. Chemical, biological and cultural methods are also employed in weeds control under intercropping system especially among maize and vegetables intercrop farms (Wolswinkel, 2006).

2.3.4 Plant Nutrient Requirement

Organic and inorganic fertilizers are required in their right quantities for vegetative growth and increase in yield for both cereals and vegetables. Maize is considered as a heavy crop and therefore requires the application of fertilizers in the right quantities and at the right time. The determination of fertilizer rate requirement will be site-specific and depends on several factors including soil, plant density climate, economics, labour supply, and logistics. The specifics will be different for each site, crop, and grower, but the principles are the same for all (Pawan *et al*, 2012).The choice of method and time of fertilizer application depends on the form and amount of fertilizer, convenience of the farmer, the efficiency and safety of fertilizer application. Farm yard manure (FYM) can also be applied at 12.5 tons per hectare (Pawan *et al*, 2012).

2.3.5 Diseases and Pest Control

Maize is susceptible to many insects such as beetles, bollworms, stalk borers and plant sap sucker such as leafhopper and maize aphids. Diseases such as bacterial (stalk rot and leaf streak), fungal (cob and tassel smut), viral (dwarf mosaic and streak diseases), and nematodes affects both cereals and vegetables (Thobatsi, 2009). The major diseases of hibiscus are stem rot and root rot. The major pests include stem borer, flea beetles, abutilon moth, cotton bollworm and cutworm (Bahaeldeen *et al*., 2012). Under the intercropping system pest and diseases often are not severe. When the pest or diseases have a specific host, it does not spread so easily through an intercrop as it does through mono cropping.

2.3.6 Maturity and Harvesting:

In intercropping system, it is good to have different crops in the mixture in different maturity dates with different times of peak demand for food, thereby reducing competition. In cereals (maize) and vegetables (roselle) intercrop as may be found in the traditional farming systems, the vegetables (leaves) are usually harvested first whiles the maize continues to mature (Wolswinkel, 2006). Harvesting must conform with regulations relating to pre-harvest intervals for agrochemicals and withholding periods. Food produce should be stored under appropriate conditions of temperature and humidity in space designed and reserved for that purpose.

The harvesting of Roselle and other vegetables begins 3–4 weeks after emergence. Harvesting of vegetables especially Roselle is done by uprooting the entire plant, cutting the top portion of the plant and or plugging the leaves and to allow for re-growth. Cutting is done at a height of 6–8 cm, leaving 3 leaves and buds for re-growth. In commercially grown crops, the whole plants are pulled out when 20–30 cm tall and are sold at the market with their roots attached. The recommended time of harvesting kenaf as a fibre crop for an optimum balance in fibre yield and quality is when about 50% of the plants are flowering. Plants are cut near the ground and tied into loose bundles that are placed upright in the field for 2–3 days to induce defoliation and drying. Stems are then graded and tied into bundles of about 10 kg and of even stem thickness (Bukenya-Ziraba *et al*, 2004).

2.4 AGRONOMIC PERFORMANCE OF MAIZE AND ROSELLE

2.4.1. Maize

Maize is grown mostly in the tropics and is well adapted to many climates. The maturity period ranges from 70 days to 210 days. The plant often grows up to 1 - 2.5m in height, though some natural strains can grow 12 m (40 ft). The stem has the appearance of a bamboo cane and is commonly composed of 20 internodes of 18 cm (7 in) length. The stem provides support to the leaves and flowers and also serves as means for water and nutrients transport. On each node grows a leaf measuring 9 cm (3.5 in) in width and 120 cm (4 ft) in length (Belfield et al, 2008). The leaves numbers per plant ranges from eight to 20 leaves, arranged spirally on the stem, and they occur alternately in two opposite rows on the stem (Plessis, 2003).

On the other hand, Roselle (*Hibiscus sabdariffa* R) is a short-day plant that is very sensitive to the Photoperiod. Warm and humid tropical climate are suitable for Roselle plants as they are exceptionally susceptible to frost and mist. The temperature range within which Roselle thrives is between 18 and 35ºC, with an optimum of 25ºC. Growth of the plant ceases at 14ºC. In tropical and subtropical regions, an altitude 3000 ft. (900 m) above sea level is suitable for growing this plant. Annual rainfall between 400 and 500 mm is necessary throughout the Roselle growing season. Roselle plants prefer well drained humus soil with a pH of 4.5 to 8.0. It tolerates floods and heavy winds (Mehdi *et al*, 2013).

2.4.2. Days to 50% Tasseling and Flowering for Both Maize and Roselle

At 43 – 56 days, maize tassels are completely visible when the plant has reached its full height and will begin to shed its pollen depending on the variety (Baqa *et al.*, 2014). Roselle plants grow and start forming flower buds within 130-150 days after sowing. However, Abubakari, 2013 reported that it takes 31 to 45 days for roselle to set flowers after planting. Flowering is induced as the days become shorter and the light intensity decreases (Bahaeldeen *et al*, 2012). Increased in the soil fertility either by the application of farmyard manure or N fertilizer increased days to 50% flowering (Oyewole *et al*., 2010).

2.4.3. Land Equivalent Ratio (LER)

The LER denotes relative land area under sole crop required to produce the same yield as obtained under a mixed or an intercropping system at the same level of management. It is the ratio of land required by pure crop to produce the same yield as intercrop.

LER = Ya/Sa + Yb/Sb; where Ya, Yb are the yields of a and b crop grown as intercrop, Sa, Sb is the yield of a and b crop grown as sole crop, LER = Yield of intercrop over yield of pure crop Pawan, (2012) and Singh, (2013).

2.4.4. Leaf Area (cm^2), Leaf Area Index (LAI) and Canopy Spread ($cm^{2)}$

The area of green leaves play significant role in different aspect of crop growth and development. Leaf area determines the fraction of incident photo synthetically active radiation (PAR) intercepted by crop canopy and ultimately dry matter production. Leaves also are the main path for transpiration and carbon harvesting. Therefore simulation of green leaf area during growing season has been a crucial component of crop growth model (Yang, 2009). In too thick plant population of maize canopy photosynthesis is negatively affected due to less light penetration in the crop canopy and more competition for available nutrients which adversely affect plant growth and development resulting in low yield. On the other hand in too thin population there is less light interception due to lower leaf area index and more weeds germinate and grow rapidly which also result in lower yield (Amanullah, 2007).

Leaf area per plant

Specific Leaf Area = -------------------------- (cm^2 g^{-1})
Leaf weight per plant

Leaf Area Index = Leaf area per plant x No of plants m^{-2} (Amanullah, 2007).

2.4.5. Grain Yield of Maize

Grain yield of maize depends partly on the final plant density. Yield also depends on the fertility of the soil and climate of that area. About 10 to 16 kg of grain are obtained from every millimetre of water used. About 3 152 kg/ha maize grains cab obtained within the rainfall range between 350 and 450 mm per annum. Several methods can be used to determine yield potential, each with its own limitations. One of the most reliable methods is long-term yield data collected by each individual producer, as this reflects inherent yield of the specific environment, as well as the effect of agronomic practices such as fertilisation, soil cultivation and plant population and managerial abilities of the producer (Plessis, 2003).

Generally, maize grows to produce cobs which contain the grains covered with husks. Cob length varies from 6.2 to 24.7 cm and cob diameter varies from 1.2 to 3.8cm depending on the varieties (Plessis, 2003). Baqa *et al*., (2014) reported that cob length ranges from 48 -66cm.

2.4.6. Leaf Yield of Roselle

Farmers harvest Roselle at different stages of growth. Some farmers do uproot the entire plant, cut the plant whiles others harvest only the leaves by plucking them and allow for continuous growth. Roselle leaves are usually harvested by farmers based on ocular observation of plant height, colour and leaf size. Right from three weeks on ward, Roselle leaves can be harvested. Harvesting of Roselle is mostly done in the morning. Roselle can produce up 71.38g of leaves per plant and 450.26 tons per hectare depending on the spacing (Obodai, 2007).

2.5. POST-HARVEST QUALITIES OF ROSELLE

Several parts of plants are harvested and use as vegetables. The parts of the plant harvested depend on the age of the plant and its life cycle. These have an effect on the handling of the vegetables. Vegetables refer to a collection of a variety of plant structures and do not represent any specific botanical group. Vegetative tissue includes leafy vegetables, stem vegetables, roots, tubers and bulbs. Flower buds, fruit, seeds and grains are reproductive tissues. According to Lokke, (2012), vegetables are classified into three main groups based on potential shelf life. These include seeds and pods; roots and tubers; flowers, buds, stems and leaves, where the latter has the shortest storage life. The common feature of green vegetables is the green colour arising from the green pigment - chlorophyll, and the presence of the green colour is a quality aspect in these types of vegetables.

2.5.1 Shelf life of Roselle

Many of the changes observed during senescence of harvested green vegetables show similarities to changes seen during natural leaf senescence, although the senescence is induced artificially at harvest due to removal of nutrient supplies (Bastien et al., 2011). For vegetables originating from vegetative tissue, senescence is unwanted and should be postponed as long as possible. The sensory quality of these vegetables is optimal right after harvest as the processes of plant senescence increase as soon as the tissue is harvested from the plant. Growth processes, such as cell division and expansion, and protein and carbohydrate synthesis usually cease upon harvest, and the metabolism goes into a catabolic or degradative mode.

The changes that take place during senescence can be seen both at a physical level (from a consumer‟s point of view) and a physiological level (what happens in the plant). Chlorophyll degradation is an obvious visual change during senescence, and it is accompanied by losses in membrane lipids and proteins, eventually resulting in cell death and textural changes. In detached leaves, cell death does not occur simultaneously across all cells in a leaf, or even within cells of a particular type; it is a gradual process that occurs in cell by cell (Bastien et al., 2011).

The rate of senescence is linked to the rate of the metabolic processes, i.e. the respiration rate.

2.5.2 Colour change/Discoloration

Colour is the most important quality attribute having influence on consumer acceptability of food as it gives the first impression of food quality. The red colour is due to presence of anthocyanins in the Roselle blends and as the concentration of Roselle extract decreased the redness decrease. The yellow colour is due to the presence of carotenoids in (mango, guava and papaya) so as the concentration of fruit juices increased in the blends the yellowness also increased (Mgaya *et al*, 2014).

2.5.3 Shrivelling

As a leafy vegetable, Roselle shoots are sold in bunches with a length of up to 50 cm. Thinned seedlings are less perishable than cut shoots; as they are sold with their roots attached and can be kept fresh by placing the roots in water. Fresh shoots are easily transported and can be kept in good condition for 1–2 days especially in shade or cool places. Sprinkling water on the leaves helps to keep them fresh. Leaves can be preserved by sun-drying. The dried product is broken into small pieces or ground to powder and used in soups. It takes relatively short number of days for the leaves to shrivel (Bukenya-Ziraba *et al*, 2004). Mass shrinkage does occur as the most important structural variation due to weight loss. This affects consumer preference and acceptance of the produce (Saeed *et al.*, 2008)

2.6 NUTRITIONAL COMPOSITION OF MAIZE AND ROSELLE

2.6.1 Nutritional composition of Roselle

Roselle just like other leafy vegetables is a good source of nutrients in the diet of people. The plant contributes immensely to the nutritional balance of people especially children, pregnant women and the aged. Leafy vegetables contain vitamins, proteins and minerals such as vitamin A, thiamine, riboflavin, ascorbic acid, niacin. The vegetables also contained good minerals with abundance of them in calcium, magnesium, sodium, and potassium, copper, nickel and manganese. The nutritional significance of the elements is almost in consonance with the standard recommended dietary allowance (Asaolu, 2012).

The leaf of Roselle is said to have 213 mg Ca, 93 mg P, and 4.8 mg Fe. Sodium and potassium are important intracellular and extracellular cations respectively. Sodium is involved in the regulation of plasma volume, acid-base balance, and nerve and muscle contraction. Vegetables when consumed in the right quantities could contribute significantly to the nutritionally marginalised population. This population is especially in developing countries where poverty and climate is causing havoc to the rural populace. The supply of minerals in many developing countries is not sufficient to meet the mineral requirements of farm animals and rapidly growing population. The Minerals required cannot be obtained by animals and therefore must be provided from plants or mineral rich water (Asaolu, 2012).

The pH of Roselle leaves play significant role in determining the taste factors and acceptability. Under low pH, fresher taste is observed, colour equilibrium shifts to more red pigments, colour hue increase and the aging potential increases. Low pH also influences sourness and as pH decreases, astringency decrease. Higher pH however gives a rounder, softer mouth feel, and unstable colour under slower polymerisation (Wyn, 2004).

Total soluble solids are an important postharvest quality attribute of Roselle leaves. The leaves contain many soluble compounds which are soluble in water. These soluble compounds include; sugars, acids, vitamin C, amino acids and some pectin which forms the total soluble acids (TSS). In the leaf, the sugar forms the most component of soluble solid. The total titratable acidity (TTA) measures the amount of acid present in a particular product - leaves of Roselle. The TTA affects the taste of the leaves. There is a relationship between pH, TSS and TTA (Buah 2013).

2.6.2 Proximate Composition of maize

The proximate composition of maize and maize products consists of protein, carbohydrates, fat, fibre and ash. These components are provided in ranges which includes; carbohydrate 44.8 – 69.6%, moisture contents 11.6 – 20% , protein content 4.5 – 9.87 , fat 2.17 – 4.43 , fibre 2.10 – 26.77 and the ash content 1.10 – 2.95% (Sule *et al.*, 2014). These figures are not in agreement with Plessis, 2003 who revealed that carbohydrates content is 84%, protein is 10.9%, fat is 4.5% and minerals content is 1.3%. However, the proximate and mineral content analysis provides substantive nutritional information for maize paramount to effective dietary guide. The moisture content will also aid in determining handling methods of the produce hence post harvest management (Sule *et al.*, 2014).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The materials and methods covers field research experiments which involve cultural practices, agronomic performance of the crops and postharvest characteristics of the intercrop arrangements. The experiment was conducted during the rainy season from July to November 2014.

3.1 STUDY AREA

The research work was conducted during the rainy season from July to November 2014. The study was conducted in Northern region at the Air force based area of Africa Rising project which is under the auspices of International Institute of Tropical Agriculture (IITA) – Tamale, Ghana. Tamale and its environs fall between latitudes $9^{0}\ 15^{1}$ and $9^{0}\ 45^{1}$ N and longitudes $0^{0}\ 30^{1}$ and $1^{0}\ 15^{1}$ W and with an altitude of 183 m (600 ft). The area experiences one rainy season from April to September/October with a peak in July / August. The mean annual rainfall is 1100 mm within 95 days of rainfall in the form of tropical showers – continuous and frequent rainfall in the tropics. Consequently, staple crop farming is highly restricted by the short rainy season. The dry season is usually from November to early April. It is influenced by the dry North-Easterly (Harmattan) winds while the rainy season is influenced by the moist South Westerly winds. The mean day temperatures range from 28^0C (December to mid-April) to 43^0C (March to early April) while mean night temperatures range from 18^0C (December) to 25^0C (February, March). The mean annual day sunshine is approximately 7.5 hours. The study area falls within the moist semideciduous belt and the soil is sandy loam.

The terrain of the land is relatively flat with isolated hills and rocks with relief between 60 metres and 150 metres above sea level. The vegetation cover is mainly grassland with shrubs and interspersed with indigenous tree species such as Shea nut *(Vitellaria paradoxa*), kapok *(Ceiba pentandra)*, baobab (*Adansonia digitata)* and dawadawa *(Parkia biglobosa*). Almost all arable crops are cultivated under rain fed. In the study area, agriculture constitutes the main economic activity engaging 60% of the people (FASDEP II, 2007). Crops commonly cultivated include; maize (Zea mays), rice (Oriza sativa), groundnut (*Arachis hypogea*), cowpea (*Vigna unguiculata*) and yam (*Dioscorea spp*). The people also engage in dry season Vegetable production around water bodies such as dams, dugouts and streams/river valleys.

3.2 FIELD EXPERIMENT

Field research trials were conducted in the rainy season from July to November, 2014 in three replications with six sub plots and treatments per replicate on the Africa rising project site in Air force based area, Tamale under the auspices of International Institute of Tropical Agriculture (IITA).

In this study, field and laboratory work were carried out. The field work was mainly on cultural practices as well as the other agronomic practices of the intercrops. It also centred mainly on laboratory analysis of chemicals and minerals post harvest characteristics.

3.2.1 Experimental Design and Treatments

Due to the similarities of the experimental units in the research, Randomised Complete Block Design (RCBD) was used for grouping the experimental units into blocks or replicates. The purpose of grouping the experimental units was to have the units in a block as uniform as possible so that the observed differences between treatments will be largely due to "true" differences between treatments.

The treatments are:

- Treatment 1 = 1:1 (This arrangement consist of one row of maize and one row of Roselle in an alternate manner within a plot with the spacing 100cm by 40cm).
- Treatment 2 = 1:2 (This arrangement consist of one row of maize and two rows of Roselle in an alternate manner within a plot with the spacing 100cm by 40cm)
- Treatment 3 = 2:1 (This involves two rows of maize and one row of Roselle in an alternate manner within a plot with the spacing 100cm by 40cm)
- Treatment 4 = 2:2 (this involves two rows of maize and two rows of Roselle in an alternate form within a plot with the spacing 100cm by 40cm)
- Treatment 5 = sole maize (31,250 plants/ha at 80cm x 40cm)*2
- Treatment 6 = sole Roselle (41,666 plants/ha at 60cm x 40cm)*2

Field lay out is as follows;

REPLICATE 1 ALLEY REPLICATE 2 ALLEY REPLICATE 3

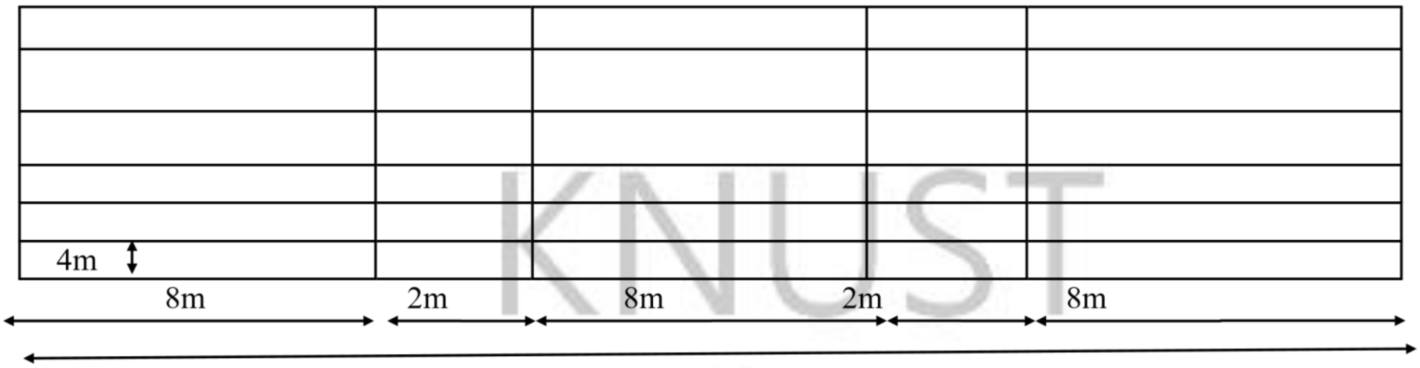

Figure 1: Experimental lay out.

3.2.2 PLANTING MATERIALS

Omankwa maize variety was used for the study. It has a 90 day maturity period and tolerant to Striga. The variety used for this research work was provided by IITA, Tamale. The planting medium was developed by savannah agriculture research institute of the centre for scientific and industrial research (CSIR-SARI). The Roselle (*Hibiscus cannabinus L.*) variety was obtained from IITA and used in the intercropping system with average seed viability test of 98%.

3.2.3 CULTURAL PRACTICES:

i. Land Preparation and Planting

The land was prepared in July using tractor method of land preparation in the community. The ploughed land was measured 29m long and 28m width. The land was demarcated into replications. Each replicate measures 29m by 8m, two meters were left in between replications. Six plots were also measured in each replicate. This gives a total of 18 plots in all the three replicates. Each plot measures 4m*8m. The total experimental area is 29m *28m = 812m^2.

Both maize and Roselle were planted directly on the same day using two seeds per stand. The sole maize was planted using a planting distance of 80cm by 40cm. Sole Roselle was planted using

60cm by 40cm whiles the intercrop systems were planted using a planting distance of 100cm by 40cm. Plant establishment count was conducted to ascertain the plant population per hectare.

ii. Weeding

Two separate weeding were done. First weeding was done in first week of August whiles the second was done in late August. *Striga hermontica* (witch weed) was a very serious pest among the maize plants. Manual weeding was done using the hand hoe among all the treatment plots.

iii. Fertilizer application:

Basal application of fertilizer was adopted. 250kg of N.P.K. (15:15:15) was used at three weeks after planting and 125kg of sulphate of ammonia was used six weeks after planting per hectare.

iv. Pest Control

Insect pest were also controlled among the Roselle plants using lumber pesticide on two separate times. The spraying was done with the aid of a nap sack sprayer.

3.2.4 DETERMINATION OF PARAMETERS

Sampling of plants was done for data collection. Three middle rows were sampled for data collection of sole maize and Roselle whiles two middle rows were tagged for each of the maize and Roselle in the intercrop arrangements. In all, 27 plants were used for the sole maize and Roselle and 18 plants for the intercrop system. The following parameters were studied fortnightly; plant height, number of branches, plant girth, canopy size, leaf number and leaf area index.

i. **Plant Height**

Plant height was determined from the base of the plant to the terminal growing point using the meter rule. Eighteen plants were sampled from the middle rows for maize and Roselle under the intercropping system whiles twenty seven plants from the middle rows under the sole maize and Roselle were used to determine the height per plant fortnightly of both maize and Roselle and the mean values determined by finding the average measurement of plant height.

ii. **Plant Girth**

This was measured from the base of the plant at 10cm above the ground, using Vernier callipers. Eighteen plants from the middle rows under the intercropping system were sampled and used whiles twenty seven plants were sampled from the sole maize and Roselle and used to estimate the girth per plant fortnightly. The mean value was then determined by finding the average of all the measurements of plant girth.

iii. **Canopy Spread**

The canopy spread was determined as the mean spread at two positions at right angles to each other.

iv. **Number of Branches per Plant**

The branches of Roselle was determined fortnightly per plant by simple counting the number of branches per plant using eighteen Roselle plants from the middle rows and twenty seven from the sole Roselle. Averages of the number of branches were then determined by dividing the sum total of branches counted by the number of plants over the period.

v. Number of leaves per plant

Fully developed leaves per plant were counted to establish the number of leaves per plant from the eighteen plants in the middle rows under the intercropping system and twenty seven plants under the sole maize and Roselle fortnightly. The averages of the number of leaves per plant were then determined by dividing the total number of leaves by total number of plants tagged.

vi. Leaf area / Lea index

The leaf area was measured per plant by calculating the length together with the width of each leaf in a treatment plot. Eighteen tagged plants from the middle rows under the intercropping system and twenty seven plants from the middle rows under the sole maize and Roselle were used for the estimates. The product was then multiplied by the correction factor.

Leaf area (LA) = k (L * w); where

K stands for correction factor (0.75 for cereals); L stands for leaf length, w stands for leaf width and * stands for times.

The leaf area index (LAI) was also calculated using the formula; LAI = K (L * W) /a; where A stands for land area.

vii. **Striga Count**

Striga count was determined by counting the number of maize plants affected by Striga within the treatment /plot.

viii. **Days to 50% Tasseling and Flowering**

Days to 50% flowering and tasseling was assessed by counting from the first day plants began flowering or tasseling till the day 50% of the plants flowered or tasselled for both maize and Roselle. The eighteen tagged plants for each of maize and Roselle plants under the intercropping systems and the twenty-seven tagged plants for both sole maize and sole Roselle plots were used for the data collection and the outcome was expressed as a percentage of the total.

3.2.5 DETERMINATION OF YIELD PARAMETERS

i. Cobs Number per Plant

The cobs number per plant was calculated by estimating the average cobs per plant from the eighteen tagged plants in the intercrop system and twenty seven plants from sole maize.

ii. Cobs Length

This parameter was estimated using the meter rule. Each cob from the eighteen tagged plants in the intercrop system as well as the twenty seven plants from sole maize were measured using the meter rule and the averages determined and recorded.

iii. Cobs girth

This parameter was determined with the aid of venire callipers. The girths of the eighteen tagged plants in the intercrop system as well as the twenty seven plants in the sole maize were measured and the averages calculated.

iv. Grain

Maize yield was determined by de-husking and shelling the cobs in the eighteen tagged plants in the intercrop system as well as the twenty seven plants under the sole maize. Grain weight was determined with the aid of a digital scale and then averages per meter square was calculated and extrapolated in kilogram per hectare.

v. Total Roselle Leaf Yield

The total Roselle leaf yield was measured by harvesting the leaves of the eighteen plants tagged in the intercrop system and twenty seven plants in the sole Roselle. The weights of the leaves were then determined using a digital scale and the average weight per plant calculated in kilogram. This was then extrapolated in kilogram per hectare.

Leaf yield (kg) Ty = Harvested area (m)

vi. Non-Edible/ Non-Sellable Yield

This was determined by sorting out the non-sellable leaves (over matured, diseased and yellow leaves) amongst the edible leaves in the eighteen tagged plants in the intercrop system and twenty seven tagged plants of sole Roselle. The weights of the non-edible leaves were then determined per plant and extrapolated in kilogram per hectare. This is given as;

Ny = Ty – My;

Where; Ny = Non sellable yield, Ty = total yield, and My = marketable yield.

vii. Edible /marketable yield*:*

The marketable yield was determined after sorting out the non-sellable leaves. Marketable yield was calculated from the eighteen tagged plants in the intercrop system as well as the twenty seven plants of sole Roselle. The weights per plant were determined using digital scale and extrapolated in kilogram per hectare. This is given as;

My = Ty – Ny

Where; My = marketable yield, Ty = total yield, and Ny = non-sellable yield.

viii. Land Equivalent Ratio (LER)

Land equivalent ratio describes the relative land area under sole crop required to produce the same yield as obtained under a mixed or an intercropping system at the same level of management. It is the ratio of land required by pure crop to produce the same yield as intercrop. LER was calculated as follows;

LER = Ya/Sa + Yb/Sb

Ya, Yb is the yield of a and b crop grown as intercrop, Sa and Sb is the yield of a and b crop grown as sole crop, LER = Yield of intercrop over yield of pure crop and the results compared with one (Pawan, 2012).

3.3 LABORATRORY EXPERIMENT

3.3.1 MAIZE AND ROSELLE SAMPLES PREPARATION

Samples of Roselle fresh leaves from the various treatments were harvested; oven dried and then converted them into powder and maintaining the treatment labels. The maize cobs were dehusked, shelled and samples of the grains collected from the various treatments. The grains were then oven dried and turned into powder for the analysis of chemical and nutritional contents. The powdered maize grain were pinched at 2g and mixed with clean hot water. The mixture or solution was then filtered and used for the proximate determination of maize.

3.3.2 DETERMINATION OF PROXIMATE COMPOSITION O MAIZE AND ROSELLE

The nutritional composition analysed includes; minerals, chemicals (pH, TTA and TSS), and proximate analysis (crude protein, crude fibre, carbohydrates, crude fats). The proximate compositions of component crops were determined using the AOAC (1990) procedure.

3.3.2.1 Crude Fat Content Determination

Two grams of maize sample was loosely wrapped with a filter paper and put into the thimble which is 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 received as mass of fat and is expressed percentage of the sample.

The percentage oil content was calculated;

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

3.3.2.2 Crude Fibre Determination

Two grams of maize sample was put into 200 ml of 1.25% of H_2SO4 and boiled for 30 minutes. The solution and content then poured into bushier 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.

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.

3.2.2.3 Determination of Ash Content

Two grams of each of the maize and Roselle samples were 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.

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

3.3.2.4 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

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.

3.3.2.5 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

3.3.2.6 Determination of Mineral Elements

The mineral elements were determined using the analytical method (Hack, 2000). Samples obtained through ashing were used for this procedure which was the white fluffy mas. Five millilitre of concentrated hydrochloric acid was used to digest each of the ash content in a glass petri dish. The mixture was transferred to 50 ml chemical flask using distilled water. Particles which cannot dissolve and would cause contamination were filtered off using Whitman"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 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 curvetted were then introduced into the sample chamber where the digital score of the samples were read and recorded.

3.3.2.6 Number of Days for Roselle Leaves to Change Colour and Shrivel

Roselle leaves were harvested from the eighteen plants in the three middle rows in the intercrop system as well as the twenty seven plants in the sole Roselle and monitored for days to change colour and shrivel. The leaves were harvested in the morning and placed under shade. Later, leaf samples were spread out on flip chart paper labelled according to the treatments. The number of leaves that changed colour, and shrivelled each day were monitored for a maximum of five days. The cumulative percentages were then calculated for days to change colour and shrivel for the treatments.

CHAPTER FOUR

4.0 RESULTS

The research results showing the different agronomic growth stages, yield and postharvest qualities in the maize – Roselle plant arrangements are provided below. The postharvest results include shelf life - number of days for Roselle leaves to change colour, shrivel and dry. Also, minerals, and proximate analysis of both maize and Roselle are studied and provided below. The total titratable acids, total soluble acids and pH of Roselle are also discussed.

4.1 EFFECT DIFFERENT INTERCROP ARRANGMENETS ON AGRONOMIC CHARACTERISTICS OF OMANKWA MAIZE VARIETY

4.1.1 Plant Establishment Count

There were significant differences ($P \leq 0.05$) between intercrop arrangements of maize in the maize-Roselle plant arrangements. The study showed that two rows of maize and one row of Roselle (1:2) resulted in the highest establishment count compared with 1:1, 2:1, 2:2 and sole maize. The least percentage of establishment count was recorded by treatment 2:2 (94.7%). 1:2 arrangements were 1.05 times more in establishment count than the least. However, there were no significant differences among the rest.

4. 1.2 Plant Height

There were no significant differences ($P \leq 0.05$) in plant heights of maize at 4, 6 and 8 weeks after planting in the maize – Roselle intercrop arrangements. In these arrangements, sole maize grew taller (124.7cm) at the eighth week after planting than the other arrangements. Two rows of maize and two rows of Roselle (2:2) however produced the least height (103.8cm). The difference in height between the tallest and the shortest is 20.9cm. Sole maize therefore grew

1.2cm times the least.

4.1.3 Plant Girth

There were no significant differences ($P \leq 0.05$) in plant girth at 6 and 8 weeks after planting of maize in the maize and Roselle intercrop arrangements. However, at week six, 1:2 arrangements produced the highest girth and the lowest at week eight whiles 2:2 intercrop arrangements recorded least girth size at week six and the highest at the eighth weeks after planting.

4.1.4 Number of Leaves per Plant

No significant differences ($P \leq 0.05$) with regards to maize number of leaves per plant at 4, 6 and 8 weeks after planting were recorded in maize – Roselle intercrop arrangements. However, 2:2

arrangements produced the highest number of leaves at the eighth week after planting than the rest. The least number of leaves per plant was produced by 1:1 arrangement at the eighth week.

4.1.5 Leaf area and Leaf area index (LAI), Striga distribution and 50% tasseling at eight weeks after planting

There was no significant difference (P≤0.05) in maize leaf area and leaf area index between treatments in the maize and Roselle intercrop arrangements. No significant difference (P≤0.05) with regards to Striga distribution among maize plants was recorded between treatments.

Similarly, there was no significant difference (P≤0.05) with regards to 50% tasseling at eight weeks between treatments.

4.1.6 Maize No. cobs per plant, Cob length, Cob girth and Cob weight after harvesting

There were no significant differences (P≤0.05) in number of cobs per plant, cobs length, cobs girth and cobs weight between treatments. However, treatment 2:1, 2:2 and sole maize recorded the highest number of cobs per plant and treatment 1:2 recorded the least number of cobs per plant. Similarly, treatment 2:2 recorded the longest cob length (11.5cm) in the intercrop arrangements and treatment 2:1 recorded the shortest (9.9cm). Also, the highest cob girth was produced by 1:1, 2:1 and sole treatment (3.7cm each) whiles treatment 1:2 and 2:2 recorded the least cob girth (3.6cm each). The highest average cob weight per plant was produced by sole treatment (81.0g). Among the mixed crop arrangements, 2:2 intercrop arrangement recorded highest cob weight (77.3g) whiles the least was recorded by the 1:2 (61.3g). Sole maize is therefore 1.32 times higher than the least and 1.05 times higher than 2:2 - the highest among the mixed crop arrangements.

Table 4.1: Crop Establishment count, plant height, plant girth, and leaf numbers of maize in maize-Roselle intercrop arrangements.

Intercrop Arrangements	Establishment Count	Plant Height at 8 weeks (cm)	Plant Girth at 8 weeks (cm)	Leaf numbers at 8 weeks
1:1	98.7	110.8	2.16	20
1:2	100	109.4	2.04	21.67
2:1	99.7	117.6	2.09	22.33
2:2	94.7	103.8	2.27	23.00
Sole Maize	98.7	124.7	2.05	21.00
Turkey Hsd (0.05)	23.37			5.252

Table 4.2: Cobs number, cob length and cob weight of maize in maize-roselle intercrop arrangements.

Intercrop Arrangements	Number of cob	Cob length(cm)	Cob Girth(cm)	Cob weight(cm)
1:1	1.6	10.9	3.7	69.6
1:2	1.4	10.2	3.6	61.3
2:1	1.7	9.9	3.7	66.4
2:2	1.7	11.5	3.6	77.3
Sole Maize	1.7	11.2	3.7	81.0
Turkey Hsd (0.05)	0.42	3.45	0.38	31.65

4.2 EFFECT OF INTERCROP ARRANGEMENTS ON THE GRAIN YIELD OF MAIZE

There were significant differences ($P \leq 0.05$) between treatments in maize grain yield of maize - Roselle intercrop arrangements. The study showed that sole maize had the highest grain yield per hectare (1903.6kg per Ha) under the planting distance of 80cm by 40cm. However, 1:2 arrangements produced the least grain yield per hectare (815kg per Ha) under 100cm by 40cm planting distance. There were no significant differences between treatments except 1:2 arrangements. Under the mixed crop arrangements of 1:1, 1:2, 2:1 and 2:2, two rows of maize and two rows of roselle (2:2) yielded the highest grain (1685.4kg/Ha) than the rest. Sole maize therefore yielded 2.34 times more than the least grain yield (1:2) and 1.13 times more than the 2:2 in the arrangements. Similarly, 2:1 arrangement yielded good grain results than 1:1 and 1:2.

Table 4.3 Grain yields of maize

INTERCROP ARRANGEMENTS	GRAIN YIELD (KG)
1:1	1152.1
1:2	815.1
2:1	1315.1
2:2	1685.4
sole maize	1903.6
Turkey HSD (0.05)	**1088.50**

4.3 EFFECT OF DIFFERENT INTERCROP ARRANGEMENTS ON THE AGRONOMIC YIELD DATA OF ROSELLE

4.3.1 Plant Establishment Count and Plant Height after Planting Roselle

The results indicated that there were no significant differences (P≤0.05) in Roselle plant establishment count and plant height at 4, 6, 8 and 10 weeks after planting in maize – Roselle intercrop arrangements. However, in mere comparism 2:2 arrangements had the highest establishment count and the least was recorded by sole Roselle arrangement.

Similarly, 1:2 arrangements had the highest plant height at week four up to week ten. The least was recorded by 2:1 and 2:2 arrangements.

4.3.2 Number of Roselle Leaves per Plant

The results showed significant differences ($P \leq 0.05$) between plant arrangements in Roselle number of leaves per plant at four weeks after planting. The 1:2 arrangements of Roselle recorded the highest number of leaves (21.33) per plant than 1:1, 2:1, and sole Roselle in the maize and Roselle intercrop arrangements. The least was produced by treatment 2:2 (17.33) in the maize and Roselle intercrop arrangements. There were no significant differences between the intercrop arrangements 1:1, 2:1 and sole Roselle. The highest Roselle leaves numbers per plant is 1.23 times the lowest. On the other hand, there were no significant differences between the intercrop arrangements of Roselle number of leaves per plant at 6, 8 and 10 weeks after planting.

4.3.3 50% flowering at eight weeks

There were no significant differences ($P \leq 0.05$) between treatments for 50% flowering at eight weeks after planting of Roselle in the maize - Roselle intercrop arrangements. Plant arrangements 1:1, 1:2, 2:1 recorded the same values of 50% flowering at 8 weeks after planting.

However, arrangement 2:2 recorded the least.

4.3.4 Canopy Spread

The study revealed that there were significant differences between intercrop arrangements of Roselle canopy size. In the study, plant arrangement 1:1 had the highest canopy spread than 1:2, and 2:1 treatments. The least was recorded by 2:2. In the arrangements, 1:1 is 1.26 times the least and 1.04 times the 1:2 arrangements. However, there are no significant differences between arrangements 1:2 and 2:1.

4.3.5 Leaf Yield of Roselle (kg per Hectare)

The results indicated highly significant differences (P≤0.05) between treatments of Roselle leaf yield per hectare in the maize and Roselle intercrop arrangements. The sole Roselle arrangement produced the highest leaf yield (21209.3kg) per hectare than 1:1, 2:1, and 2:2 arrangements. The least leaf yield was observed in 1:2 (7326.1kg) arrangements. Among the mixed crop (intercrop) arrangements, 2:2 (16981.3kg) performed better than 1:1, 1:2 and 2:1. Sole Roselle leaf yield is 1.25 times 2:2 arrangements and 290 times the least. However, intercrop arrangements 1:1 and 2:1 are not significantly different from each other.

4.3.6 Marketable Yield of Roselle

There were no significant differences (P≤0.05) between intercrop arrangements of maize – Roselle in marketable yield of Roselle leaves. The results revealed that all the intercrop arrangements performed better in the marketable yield except 1:2 (7321kg/Ha). The sole Roselle provided the highest marketable yield (21204kg/Ha) than 2:2, 1:1 and 2:1intercrop arrangements. 2:2 (16979kg/Ha) arrangements performed better under the mixed crop (intercrop) stands of 1:1, 2:1 and 1:2 arrangements. Meanwhile, there are no significant differences between arrangements 1:1, 1:2, 2:1 and 2:2. Sole Roselle is therefore 2.9 times the least and 1.25 times 2:2 arrangements. Similarly, 2:2 yielded 2.32 times the least (1:2).

Table 4.4: Plant Establishment count, Plant Height**(cm)** at 10 weeks, Leaf number at 8 weeks, plant girth(cm) at 8 weeks, 50% flowering, canopy spread, leaf yield and marketable yield after planting.

Treatments	**Plant Establishment count**	**Plant height(cm) at 10 weeks**	**Leaf no. at 10 weeks**	**Plant girth(cm) at 8 weeks**	**50% flowering**	**Canopy spread**	**Leaf yield (kg/Ha)**	**Marketable yield (kg/Ha)**
1:1	98.3	203.7	511	1.94	61.3	1826.7	15003.9	15001
1:2	98	224.7	474.67	1.83	61.3	1749.7	7326.1	7321
2:1	98.3	195	499.67	1.83	61.3	1737.3	14660.9	14658
2:2	99.3	195	500	1.91	60	1450	16981.3	16979
sole Roselle Turkey	97.3	203	400	1.74	61.3	**-**	21209.3	21204
HSD (0.05)	**6.77**	**40.78**	**176.82**	**0.536**	**2.91**	**333.4**	**4380.6**	**4372.2**

4.4 EFFECT OF DIFFERENT INTERCROP ARRANGEMENT ON THE PRODUCTIVITY AND PROFITABILITY OF MAIZE AND ROSELLE.

4.4.1 Land Productivity

The results indicated that all the intercrop arrangements have advantages of land use over the sole cropping of maize and Roselle except 1:2 arrangements. Two rows of maize and two rows of Roselle (2:2) in the intercrop arrangement recorded the highest percentage of land saved (40.69%) in Land Equivalent Ratio (LER) than the other intercrop arrangements. 1:2 does not save land as 29.27% of the land is required to produce equal yields of sole cropping.

Table 4.5: E**FFECT OF DIFFERENT INTERCROP ARRANGEMENT ON** LAND PRODUCTIVITY MAIZE AND ROSELLE.

Intercrop Arrangements	**Land Equivalent Ratio (LER)**	**% Land saved**	**Profitability (Ghc)**	**Percentage Profit Accrued (%)**
1:1	1.3	23.82	1860.57	40.85
1:2	0.77	-29.27	34.61	1.268
2:1	1.38	27.65	2135.16	44.22
2:2	1.69	40.69	3223.93	54.48
Sole maize			1113.54	29.25
Sole Roselle			486.85	15.31

4.4.2 Economic Profitability

The study showed that 2:2 intercrop arrangements had the highest percentage of profit accrued (54.48%) and the least percentage of profit was recorded by 1:2 arrangements (1.268%). All the intercrop arrangements produced higher profits margin than the sole cropping of maize (29.25%) and Roselle (15.31%) except 1:2 arrangement. 2:2 arrangements yielded 42.97 times the least (1:2) and 1.86 times the sole maize and 3.56 times the sole Roselle.

Table 4.6: Effect of different intercrop arrangement on Economic profitability of maize and Roselle

Intercrop Arrangements	Profitability (GH₵)	Percentage Profit Accrued
1:1	1860.57	40.85
1:2	34.61	1.268
2:1	2135.16	44.22
2:2	3223.93	54.48
Sole maize	1113.54	29.25
Sole Roselle	486.85	15.31

4.5 EFFECT OF DIFFERENT INTERCROP ARRANGEMENT ON THE PROXIMATE COMPOSITION O ROSELLE LEVES

4.5.1 Minerals Composition of Roselle Leaves

There were significant differences in the magnesium content of Roselle leaves as influenced by plant density arrangement in the intercrop system. The results indicated that 1:1 arrangements recorded the highest percentage of magnesium concentration in the Roselle leaves (0.8%). The least percentage was recorded by 2:2 intercrop arrangements (0.30%). Intercrop arrangements 1:1.

1:2 and 2:1 are not significantly different from each other. Sole Roselle differs significantly from the rest of the arrangements. The magnesium concentration in the Roselle leaves as discovered by this research work was high in all the arrangements ranging from 0.4g to 0.8g except as compared with the recommended daily intake.

However, the intercrop arrangements have no effects on Calcium (Ca), Copper (Cu), Nitrogen (N), Phosphorus (P), Lead (Pb) and Zinc (Zn) concentration in the leaves of Roselle.

Table 4.7: Mineral composition of Roselle leaves

Intercrop Arrangements	**Mg (%)**	**Ca (%)**	**Cu ($mgkg^{-1}$)**	**N (%)**	**P (%)**	**Pb ($mgkg^{-1}$)**	**Zn (%)**
1:1	0.8	0.6267	9.4167	2.47	0.4133	10.117	556.2
1:2	0.7	0.7367	7.5	3.1767	0.4067	10.733	981.33
2:1	0.7	0.6833	10.433	3.3133	0.39	1.9	431.05
2:2	0.3	0.2133	12.8	3.26	0.2367	32.517	351.4
Sole Roselle	0.4	0.13	15.217	2.9267	0.4033	8.2	172.72
Turkey HSD (0.01)	**0.39**	**1.843**	**14.63**	**1.797**	**0.425**	**50.99**	**1259**

4.5.2 Chemical Composition of Roselle Leaves

The study showed that there were no significant differences ($P \leq 0.01$) between intercrop arrangements of maize – Roselle with respect to pH, TSS and TTA. pH ranged between 3.6 and 4.9, while TSS and TTA had ranges 0.9-1.9**%** and 2.3-2.7**%**.

Table 4.8: Chemical Composition of Roselle Leaves

Intercrop Arrangements	**pH**	**TSS (% Brix)**	**TTA (%)**
1:1	4.3	1.3667	2.4433

1:2	3.7333	1.9333	2.69
2:1	4.6	0.8667	2.3333
2:2	3.6	1.5667	2.441
Sole Roselle	4.8667	0.7333	2.67
Turkey HSD (0.01)	**2.325**	**1.3578**	**1.259**

4.5.3 Cumulative Colour Change of Roselle Leaves

Significant differences (P≤0.05) in colour of Roselle leaves were observed amongst treatments from day one today two. Treatment 1:1 (one row maize and one row Roselle) had the lowest percentage change in leave colour from day one (11.11%), day two (35.6%) and day three (82.2%) after harvest (Table 4.8). This was followed by treatment 1:2 (one maize two Roselle) for day one (17.3%) and day two (55.6%). By Day 4 all the intercrop arrangements (100%) had had leaf colour change from the original green colour to brown.

Table 4.9: Cumulative colour change of Roselle leaves

Intercrop Arrangement	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**
1:1	11.11	35.6	82.2	100	100
1:2	17.8	55.6	100	100	100
2:1	28.9	66.7	93.3	100	100
2:2	26.7	57.8	88.9	100	100
Sole Roselle	26.7	66.7	100	100	100
LSD (0.05)	**9.394**	**24.257**	**31.001**		

4.5.4 Cumulative Percentage Roselle Leaf Shrivel

The study revealed that there were significant differences (P≤0.05) between the various intercrop arrangements of maize and Roselle for only Day 1 (Table 4.9). One row of maize and one row of Roselle resulted in the least percentage shrivel (6.1%) as against 12.59% (1:2), 20.00% (2:1), 26.67% (2:2). On day 2 all the Roselle leaves had shrivelled irrespective of the intercropping arrangement.

Table 4.10: Cumulative percentage shrivelled of Roselle leaves

Intercrop Arrangement	Day 1	Day 2	Day 3	Day 4	Day 5
1:1	6.069	100	100	100	100
1:2	12.59	100	100	100	100
2:1	20	100	100	100	100
2:2	26.66	100	100	100	100
Sole Roselle	40	100	100	100	100
LSD (0.05)	**2.912**				

4.6 PROXIMATE ANALYSIS OF MAIZE GRAIN AS AFFECTED BY MAIZE AND ROSELLE INTERCROP ARRANGEMENT

The study showed that there were significant differences (P≤0.01) between treatments for crude protein, crude fibre, crude fat and carbohydrates content in the maize – Roselle intercrop arrangement. However, there were no significant differences (P≤0.01) between treatments for ash content in the intercrop arrangements. Among the treatments for crude protein, two rows of maize and two rows of Roselle (2:2) had the highest crude protein concentration in the grains (21.54) whiles the least (8.89) was observed in one row of maize and one row of Roselle (1:1) intercrop arrangement. Also, among the treatments for crude fibre, two rows of maize and one row of Roselle (2:1) in the intercrop arrangement produced the highest crude fibre (1.87) and followed by (1.82) two rows of maize and two rows of Roselle (2:2) intercrop arrangement. The least (1.23) crude fibre content was observed in one row of maize and two rows of Roselle (1:2).

Similarly, proximate analysis for crude fat revealed that two rows of maize and one row of Roselle (2:1) had the highest crude fat (0.10) in the intercrop arrangements and this followed by two rows of maize and two rows of Roselle (2:2). However, the least (0.05) crude fat was observed in one row of maize and two rows of Roselle (1:2).

For carbohydrates concentration between the treatments, two rows of maize and two rows of Roselle (2:2) had the highest levels of carbohydrates (82.23) in this research work which is significantly higher than the least. The least (79.69) carbohydrates concentration was observed in intercrop arrangement one row of maize and two rows of Roselle (1:2).

Table 4.11: Proximate composition of maize grain

Intercrop Arrangement	**Crude Protein (%)**	**Crude fibre (%)**	**Crude fat (%)**	**Carbohydrates (%)**	**Ash (%)**
1:1	8.8	1.24	0.073	80.36	0.013
1:2	9.22	1.23	0.053	79.6	0.023
2:1	11.09	1.87	0.103	81.59	0.023
2:2	21.54	1.82	0.08	82.23	0.03
LSD (0.01)	**8.56**	**0.23**	**0.028**	**1.57**	**0.025**

CHAPTER FIVE

5.0 DISCUSSION

5.1 EFFECT OF DIFFERENT INTERCROP ARRANGEMENTS ON THE AGRONOMIC PHYSIOLOGY OF MAIZE (OMANKWA VARIETY)

5.1.1 Plant Establishment Count of Maize

Maize and Roselle intercrop arrangement did have effects on the establishment count. This observation has not been explained by literature available. However, it could be due to synergistic effect of Roselle on maize performance resulting in improved establishment with increasing Roselle rows. Fbabantunde (2003) reported that Roselle plants were negatively affected by intercropping with cereals more than with legumes. This observation made by the author suggests that maize probably benefitted from the presence of Roselle in the intercrops. During the growth of the plants it was observed that Roselle plants grew faster and taller at the initial stages than maize and provided sufficient protection against sunlight as well as creating micro-desirable climate for maize. This probably resulted in the maize plants establishing better with increased rows of Roselle. The findings in this study suggest that Roselle could be beneficial in maize establishment at the early stages of growth of growth of maize.

5.1.2 Grain Yield

The findings indicated grain yield differences in all the intercrop arrangements. The yield differences could be attributable to the planting distances (plant density) and establishment of maize. As indicated earlier in this write up, there was complimentarity of maize and Roselle in the intercrop arrangements in the initial stages. However, the later part of the growth resulted in competition of component crops. Roselle plants grew taller and probably shaded the maize thereby reduced light interception. Thobatsi (2009) reported that increasing the planting distance of maize reduces the grain yield. According to Chandrasekaran *et al*. (2010), yield of a crop depends on the final plant density which also depends on the germination and establishment percentage and the survival rate in the field. It was also observed that increasing equal number of rows of component crops affords yield increase of maize. This may be due to synergistically interaction of component crops, reduced competition for light, water, space, nutrients and air. Asante (1993) indicated that two rows of maize and two rows of Roselle give the best grain yield due to reduced competition of component crops and ability to reduce shading and striga infestation.

Grain yield was high in sole maize because the intercrop arrangement was free from competition of component crops for light, space, water and other resources. Asante (1993) reported that pure stand of maize makes efficient utilization of resources since it is free from competition with other crops. The report further indicated that pure stand of maize provide higher yield than mixed cropping. It is therefore evident that the intercrop arrangement of 1:2 should not be an option. However, 2:2 arrangements should be desirable.

5.2 EFFECT OF DIERENT INTERCROP ARRANGEMENTS ON THE AGRONOMIC AND YIELD PERORMANCE OF ROSELLE *(Hibiscus cannabinus L.)*

5.2.1: Number of Roselle leaves per plant

The findings of the research indicated that Roselle leaf numbers per plant at four weeks after planting performs better in all the intercrop arrangements. In the initial stage of growth (not exceeding 4 weeks after planting), Roselle leaf numbers increase per plant in one row of maize and one row of Roselle arrangement. This could be due to reduced competition for light, nutrients, water and space. Within the same period, increasing the number of rows of component crops equally results in low number of leaves per plant. Increasing rows of Roselle and reducing rows of maize can possibly increase leaf numbers per plant of Roselle in the intercrop arrangement in the initial stages. As time goes by at weeks 6 – 10 Roselle leaf numbers per plant in all arrangements of maize and Roselle intercrop system becomes insignificant. This may be due to low competition for light, nutrients, water, space and air as the plant matures. At week four, the Roselle attains the stage of vigorous growth and requires nutrients, light, space and water for growth. This may result in competition for the various resources, 1:1 arrangement therefore affords the best complimentarity for growth. Similar reports made by Abukari (2013) stated that Roselle number of leaves per plant is not affected by plant density so long as it does not reach the state of competition. This means that at four weeks after planting, 1:2 arrangement is ideal to provide high number of leaves per plant.

5.2.2 Canopy Size

The canopy spread was more evident in 1:1, 1:2 and 2:1 arrangements. This may be attributable to more number of leaves produced per plant. Roselle grew taller and therefore reduced light interception of the component crop (maize) resulting in low grain yield of maize. However, two rows of maize affords high grain yield due to low shading of the maize. The high canopy spread among the one row of maize and one row of Roselle may be due to inter and intra row competition of component crops for light and other limited resources leading to taller Roselle plants and shading of the maize.

Babatunde (2003) indicated that Roselle growth performance is better in association with legumes than with cereals, presumably because of more shading competition with the cereals. As the rows of component crop increases, the canopy spread reduces due to low competition of the intercrop. It will therefore be agronomically efficient to intercrop maize and Roselle in 2:2 arrangements than 1:2.

5.2.3 Leaf Yield of Roselle (kg per Hectare).

The high leaf yield of sole Roselle may be attributable to high establishment count as this set the pace for high yield. High plant density due to inter row close spacing might have also contributed to the high yield. Diovany *et al*. (2011) reported that Roselle fresh weights are significantly influenced by the spacing between plants. During the study, it was also observed that Roselle grew tall and produced a lot of leaves due to non-component crop completion for light, water, nutrients, space and air. Sole Roselle therefore made efficient use of the productive resources. Babatunde (2003) reported that the yield of Roselle is high when it is on a sole stand due to non-component crop competition.

Under the intercrop arrangements, two rows of maize and two rows of Roselle (2:2) yielded much higher results (16,981.339kg per hectare) than the 1:1, 2:1 and 1:2 intercrop arrangements. It can be deduced that the 2:2 arrangement allowed for better component crop interaction and reduced completion for light, water, nutrients and shading. However, Asante 1993 reported that one row of maize and one row of kenaf produce high yield which might be due to less competition and better utilization of one or more growth resources as compared to plants in other crop mixtures. The yield advantages from the intercrops might have been achieved largely because of resource use by the component crops was more complementary than purely competitive. Complementarities of crops could have occurred because differences in plant heights and combinations of leaf canopy could have allowed better utilization of light. It could also be due to differences in the rooting depths and rooting patterns which allowed an improved utilization of the soil nutrients. This means that 2:2 intercrop arrangements should be desirable due to the combined effect of yield. However, 1:2 intercrop arrangement of Roselle should not be an option.

5.2.4 MARKETABLE YIELD OF ROSELLE (kg per hectare)

The study indicated that marketable yield of sole Roselle remains high after sorting out discoloured and deformed leaves that would not be acceptable by consumers. The fresh marketable leaf yield may also be attributed to the inter row spacing. Sole Roselle was spaced 60cm by 40cm whiles under the intercrop arrangements, Roselle was spaced 100cm by 40cm. Increased fresh leaf marketable yield could also be due to canopy spread as Roselle plants grew taller in all the treatments. Obodai (2007) showed that the better production of fresh edible and non-edible yields in the rainy season could be due to the production of maximum canopy which intercepted and absorbed substantial amount of light to increase yield. It is evident that increasing the plant spacing results in decreased fresh leaf marketable yield. Intercrop complimentarity might also be associated with high marketable yield as component crops coexisted beneficially. Abukari (2013) reported that yield of Roselle - Mesta (*Hibiscus sabdariffa L.*) decreases with increase in spacing. Two rows of maize and two rows of Roselle in the intercrop arrangements should therefore be the ultimate option for sustained increased in marketable yield.

5.3. LAND PRODUCTIVITY

The findings of the study showed that 2:2 intercrop arrangements saves significant portion of land (40.69%) that would be required by sole crops of maize and Roselle to produce the same yield. All the intercrop arrangements proved profitable at saving significant portion of land except 1:2 arrangements. Intercropping therefore affords yield advantage over sole cropping. Mazaheri *et al.* (2006) reported that intercrop arrangements generally provides yield advantage over sole cropping and 1:1 affords the best monetary value. Khan Zada *et al*. (1988) reported that on unit area basis it is profitable to have two component crops combined in the same arrangements for economic benefits of yields and land usage.

5.4 ECONOMIC PROFITABILITY

The findings of the study indicated that all the intercrop arrangements are profitable on monetary basis. 2:2 intercrop arrangements provided higher profits of GHC3223.93 per hectare which represented 54.48% of the total investment capital. All the intercrop arrangements are more profitable than the sole arrangement except 1:2 intercrop arrangements. This may be attributable to the combine effect of yields of component crops. It can also be deduced that there was complimentarity of the component crop arrangements except the 1:2 arrangement. 1:2 intercrop arrangements produced very low profit due to incompatible intercrop interaction in the arrangement resulting in competition for light, nutrients, moisture and space. This resulted in shading of the maize thereby reduced light interception hence low productivity and profitability.

Crop profitability is strongly determined by yield. Babatunde (2002), however, reported that Yield of Roselle is more reduced when intercropped with the cereals (millet and sorghum) than for the legumes (groundnut and cowpea).

5.5 QUALITY CHARACTERISTICS OF ROSELLE FROM THE INTERCROP ARRANGEMENTS

Post harvest refers to how long (period) it takes produce from the time of harvest to the final consumption. Quality is a characteristic of a product. It refers to the physical and bio-chemical properties of a substance. In its intent meaning, quality refers to the level of excellence of a substance. The quality of fruits and vegetables depends on the commodity and perception of the consumer. Quality determines the acceptability of a commodity. It is the pivot of profitability of a commodity (Lokke, 2012). Since quality is such a difficult concept, this study focused farmers" perceptions of quality and acceptability. Therefore, the following post harvest quality characteristics have been studied.

5.5.1 Minerals and Chemicals Composition of Roselle Leaves

The high concentration of magnesium in the leaves of Roselle among the 1:1 intercrop arrangement may be attributable to reduced competition of the component crops. The less competition for light results in abundance of chlorophyll molecules which contain the magnesium ion. Roselle and maize takes nutrient at different levels in the soil and therefore the 1:1 intercrop arrangement affords complimentarity in nutrient absorption at the different levels in the soil. Similar report has been provided by Asante (1993). However, increasing the number of rows of maize and Roselle in the intercrop arrangement in the case of 2:2 intercrop resulted in competition and thereby reduces light interception and hence reduced chlorophyll ions in the leaves. Asante (1993) reported that 2:2 intercrop arrangements results in competition which leads to low performance of crops. Magnesium plays significant roles in the diet of man. Taking too much of magnesium in the body may make it difficult for the body to absorb calcium. Similarly, less intake of magnesium can lead to hypomagnesaemia with irregular heartbeats, insomnia, muscle spasms and high blood pressure. The recommended daily intake of magnesium ranges from 310mg to 420mg for all ages as reported by Wyn (2004). This implies that the results obtained in this research work will meet the daily needs of magnesium in the diet of Roselle leaf meals.

The comparable minerals of Calcium (Ca), Copper (Cu), Nitrogen (N), Phosphorus (P), Lead (Pb) and Zinc (Zn) and chemicals of PH, Total Soluble Solids (TSS) and Total Titreable Acid (TTA) concentration in the leaves of Roselle suggest that the intercrop arrangements did not have any influence in the mineral and chemical concentration of Roselle leaves. This may be attributable to synergetic and complimentarity relationship of the component crops. Zinc concentration is higher (172.72mg to 981.33) than the daily recommended intake.

5.5.2 Shelf Life of Roselle Leaves

5.5.2.1 Cumulative colour change

Colour is one of the quality attributes which contributes enormously to fresh green vegetables acceptability. The general known colour of green fresh leafy vegetables especially Roselle leaves is green and this colour is highly acceptable by consumers.

During the study, it was discovered that the intercropping arrangements of maize and Roselle have influence on the fresh green colour change of harvested Roselle leaves with time. In this work, one row of maize and one row of Roselle (1:1) recorded the least percentage change in colour right from day one of harvest to the third day. This may be attributable to the fact that the maize plants provided shading to the Roselle plants from direct sun light and probably prevented colour change from the field. From day four to five, all the leaves had changed colour. This study is in line with the findings of Karanja (2009) who reported that it takes a maximum of five days for the leaves to completely change colour. Also, the highest percentage of leaf colour change was observed in sole Roselle from day one to three due to probably competition of plants for light resulting in field colour change as a result of loss of chlorophyll. The colour change in fresh leaves signifies degradation of chlorophyll hence senesces. This therefore affects preferences of consumers and consequently affects profitability (Obodai, 2007). Luvonga (2012) reported that commodity acceptability depends on colour. It therefore implies that 1:1 intercrop arrangement is the best option if a farmer wants to sell over a period of three days without losing much produce in terms of income. However, the rate of colour loss is high in sole Roselle which has adverse effects on the acceptability and profitability of Roselle leaves.

5.7.1.2 Cumulative percentage fresh Roselle leaves shrivelled

Roselle shrivels or shrinkage is the onset of drying, tissue breakdown and senesce. Shrivel refers to wrinkle and contract due to loss of water. The results of this work showed that Roselle leaves shrivel at the end of the first two days after harvest. During the first day after harvest, one row of maize and one row of Roselle (1:1) intercrop arrangement produced the least rate of fresh leaf shrivel. This may be attributable to the intercrop arrangement resulting in less competition for water, nutrients and light. It is also attributable to the maize shading the Roselle from the direct sun light and kept them green and fresh before harvest (Kennedy, 2011). Obodai (2007) alluded that Roselle leaves shrivel few days after harvesting when kept under room temperature. The intercrop arrangement of sole Roselle produced the highest rate of shrivelling. This may be attributable to close spacing that produced high plant density which resulted in competition for light, nutrients and water. This possibly contributed to onset of water loss before harvesting and hence high rate of shrinkage. Again, colour change of the fresh green leaf is an indication of senesce due to loss of the green pigment that sets the way for drying. It can therefore be concluded that 1:1 intercrop arrangement is the ideal for sell for longer period holding before the leaves shrivel.

5.6 Proximate analysis of Maize grain as affected by maize and Roselle intercrop arrangement

Proximate analysis refers to the grouping or partitioning of food constituents into crude protein, carbohydrates, crude fats, crude fibre and ash based on laboratory analysis. The partitioning of the food constituents (both nutrients and non – nutrients) provides an in-depth knowledge of the common chemicals properties of the food.

The findings of this research work showed that intercrop arrangement (two rows of maize and two rows of Roselle) had the best result of carbohydrate concentration (82.23). This may be attributable to less competition for light, water and nutrient resulting in high photosynthesis and production of carbohydrates for storage. The percentage carbohydrate reported here is higher than the findings made by Sule *et al*. (2014) and lower than that of Plessis (2003). The least percentage carbohydrate concentration in one row of maize and two row of Roselle is also slightly higher than the results reported by Sule *et al.* (2014). This implies that intercropping maize and Roselle have below ground and above ground complimentarity resulting in high accumulation of carbohydrates in the maize grain. It is therefore ideal to intercrop maize and Roselle especially two rows of maize and two rows of Roselle.

Plessis 2003 reported that the percentage concentration of crude fat in maize kernel is 4.5% whiles Sule *et al*. (2014) reported a range of 2.17 – 4.43%. These figures are higher than this research finding of 0.10%. Two rows of maize and one row of Roselle affords 0.10% crude fat concentration. This implies that the intercrop arrangements play a significant role in determining the concentration of crude fat in maize grain. Increasing the rows of Roselle and reducing the rows of maize further reduce the percentage concentration of crude fat in maize grain. This information is very useful for dieticians and diabetes patients.

The research findings also revealed that two rows of maize and two rows of Roselle (2:2) generated 21.54% crude protein in the maize grain. This finding is higher than that reported by Sule *et al*. (2014), Plessis (2003) and Ikram *et al*. (2010). The high concentration of crude protein may be assigned to complimentarity of component crops allowing for efficient use of resources. It may also be due to commensally role of the Roselle to maize by controlling the proliferation of Striga. Protein is a nutrient that is mostly required by children and pregnant women. Therefore, intercropping maize and Roselle in 2:2 arrangements increases the protein content of the maize grain.

The highest crude fibre was produced by two rows of maize and one row of Roselle (2:1) and this is in agreement with the findings of Ikram *et al*. (2010) and less than the findings of Sule *et al*. (2014). Increasing the number of rows of maize and reducing the number of rows of Roselle increases crude fibre content. This may be due to intra row competition for limited resources such as water and nutrients. The maize and Roselle intercrop therefore provides useful information for beauticians, dieticians, diabetes, pregnant women and children. Ideally, two rows of maize and two rows of Roselle is the best option.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

Generally, the effect of intercrop arrangements is more profitable than sole culture of crops. Two rows of maize and two rows of Roselle (2:2) arrangements afford better yield and profitability. This arrangement addresses the food and income security needs of rural people. The study also revealed that under the same level of management intercropping saves significant portion of land as compared with sole cropping.

The combine effects of nutritional composition of the intercrops are enormous. Both crops contribute immensely to the diet of people. This will help to address the nutritional requirements of children, pregnant women and the aged. This is likely to keep individuals in good shape and actively contributing the development process of a nation.

Similarly, vegetables by their nature are highly perishable when the parts are detached from the parent plants. The study revealed that for optimum profits, Roselle leaves should be harvested and marketed within one to two days. Any extension in the number of days for handling/marketing results in losses.

6.2. RECOMMENDATION

Roselle is an underutilized multipurpose crop providing farmers with food and cash income when other vegetables have become scarce. Processing generates additional family income, from which women benefit in particular. Use of Roselle as a vegetable or as a beverage should be promoted through research to improve cultivars, husbandry and post-harvest technologies. Applying rigorous quality standards for grading, processing and packaging will boost competitiveness in the international market. Demand for Roselle fibre is likely to increase as a result of the rising interest in natural, biodegradable fibres therefore Roselle production should be promoted for in some cases, as a biodegradable resource.

It will also be appropriate to carry out further research to improve on the cultivars, husbandry and post harvest technologies for enhanced promotion of as a vegetable.

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APPENDICES

ANALYSIS OF VARIANCE MAIZE

1. **ANALYSIS OF VARIANCE FOR GRAIN WEIGHT**

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	1284145.733	642072.867	10.18	0.0063
treatment	4	1550310.267	387577.567	6.15	0.0146

2. **ANALYSIS OF VARIANCE FOR GRAIN YIELD**

Source DF Type III SS Mean Square F Value Pr > F Rep 2 2.9210975E12 1.4605488E12 9.86 0.0069 **treatment** 4 2.2277549E12 556938721497 3.76 0.0525

3. ANALYSIS OF VARIANCE FOR ESTABLISHMENT COUNT

Source DF Type III SS Mean Square F Value Pr > F Rep 2 5.73333333 2.86666667 1.77 0.2304 **treatment** 4 54.66666667 13.66666667 8.45 0.0057

4. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 4 WEEKS

Source DF Type III SS Mean Square F Value Pr > F Rep 2 115.3510000 57.6755000 20.46 0.0007 **treatment** 4 24.9806667 6.2451667 2.22 0.1571

5. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 6 WEEKS Source DF Type III SS Mean Square F Value Pr > F Rep 2 56.0190533 28.0095267 0.50 0.6260 **treatment** 4 184.7273067 46.1818267 0.82 0.5476

6. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 8 WEEKS

Source DF Type III SS Mean Square F Value Pr > F Rep 2 5594.089293 2797.044647 40.76 <.0001 **treatment** 4 784.116267 196.029067 2.86 0.0964

7. ANALYSIS OF VARIANCE FOR PLANT GIRTH AT 6 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.39657333	0.19828667	3.60	0.0767
treatment	4	0.17497333	0.04374333	0.79	0.5609

8. ANALYSIS OF VARIANCE FOR PLANT GIRTH AT 8 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.44105333	0.22052667	2.98	0.1076
treatment	4	0.10436000	0.02609000	0.35	0.8352

9. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT 4 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	5.20000000	2.60000000	3.39	0.0858
treatment	4	3.06666667	0.76666667	1.00	0.4609

10. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT 6 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	10.80000000	5.40000000	1.98	0.2008
treatment	4	5.33333333	1.33333333	0.49	0.7453

11. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT 8 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Rep	2	19.60000000	9.80000000	2.83	0.1179
treatment	4	16.26666667	4.06666667	1.17	0.3912

12. ANALYSIS OF VARIANCE FOR NUMBER OF LEAF AREA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	109434.5333	54717.2667	31.37	0.0002
treatment	4	19458.4000	4864.6000	2.79	0.1013

13. ANALYSIS OF VARIANCE FOR NUMBER OF LEAF AREA INDEX

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.00617333	0.00308667	25.72	0.0003
treatment	4	0.00120000	0.00030000	2.50	0.1257

14. ANALYSIS OF VARIANCE FOR STRIGA COUNTS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	2170.000000	1085.000000	7.47	0.0148
treatment	4	1373.066667	343.266667	2.36	0.1396

15. ANALYSIS OF VARIANCE FOR 50% TASSELING AT 8 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	22.80000000	11.40000000	10.69	0.0055
treatment	4	4.26666667	1.06666667	1.00	0.4609

16. ANALYSIS OF VARIANCE FOR NUMBER OF COBS PER PLANT

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Rep	2	0.22129333	0.11064667	5.06	0.0381
treatment	4	0.19393333	0.04848333	2.22	0.1572

17. ANALYSIS OF VARIANCE FOR COB LENGTH

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	32.10292000	16.05146000	10.73	0.0054
treatment	4	5.20484000	1.30121000	0.87	0.5217

18. ANALYSIS OF VARIANCE FOR COB GIRTH

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	0.78916000	0.39458000	21.89	0.0006
treatment	4	0.05842667	0.01460667	0.81	0.5522

19. ANALYSIS OF VARIANCE FOR COB WEIGHT

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	3996.550413	1998.275207	15.87	0.0016
treatment	4	773.554733	193.388683	1.54	0.2802

ANALYSIS OF ANOVA ROSELLE

20. ANALYSIS OF VARIANCE FOR FRESH WEIGHT OF LEAF

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	2498574.44	1249287.22	1.09	0.3814

treatment	4	17983027.27	4495756.82	3.92	0.0475

21. ANALYSIS OF VARIANCE FOR FRESH LEAF YIELD

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	3.1331975E12	1.5665988E12	0.65	0.5473
treatment	4	3.0443351E14	7.6108377E13	31.61	<.0001

22. ANALYSIS OF VARIANCE FOR ESTABLISHMENT COUNT

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	6.53333333	3.26666667	0.57	0.5887
treatment	4	6.26666667	1.56666667	0.27	0.8882

23. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 4 WEEKS

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	177.7333333	88.8666667	10.21	0.0063
treatment	4	32.4000000	8.1000000	0.93	0.4922

24. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 6 WEEKS

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	481.7333333	240.8666667	3.79	0.0695
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
treatment	4	72.9333333	18.2333333	0.29	0.8785

25. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 8 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	2144.933333	1072.466667	14.48	0.0022
treatment	4	272.400000	68.100000	0.92	0.4976

26. ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT 10 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	3352.933333	1676.466667	8.02	0.0123
treatment	4	1769.600000	442.400000	2.12	0.1703

27. ANALYSIS OF VARIANCE FOR PLANT GIRTH AT 4 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.05329333	0.02664667	0.29	0.7566
treatment	4	0.19980000	0.04995000	0.54	0.7103

28. ANALYSIS OF VARIANCE FOR PLANT GIRTH AT 6 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.12681333	0.06340667	2.79	0.1206
treatment	4	0.01936000	0.00484000	0.21	0.9240

29. ANALYSIS OF VARIANCE FOR PLANT GIRTH AT 8 WEEKS

Source DF Type III SS Mean Square F Value Pr > F

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	0.00933333	0.00466667	0.13	0.8807

treatment	4	0.07262667	0.01815667	0.50	0.7357

30. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT AT 4 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	94.80000000	47.40000000	26.09	0.0003
treatment	4	32.26666667	8.06666667	4.44	0.0349

31. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT AT 6 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	3.3333333	1.6666667	0.02	0.9763
treatment	4	465.7333333	116.4333333	1.68	0.2467

32. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT AT 6 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	1043.200000	521.600000	1.14	0.3676
treatment	4	1323.066667	330.766667	0.72	0.6013

33. ANALYSIS OF VARIANCE FOR NUMBER OF LEAVES PER PLANT AT 10 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	3726.53333	1863.26667	0.47	0.6388
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**

treatment	4	24399.60000	6099.90000	1.55	0.2761

34. ANALYSIS OF VARIANCE FOR 50% FLOWERING AT 8 WEEKS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	34.13333333	17.06666667	16.00	0.0016
treatment	4	4.26666667	1.06666667	1.00	0.4609

35. ANALYSIS OF VARIANCE FOR MARKETABLE YIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	20429379.4	10214689.7	1.15	0.3653
treatment	4	309800972.4	77450243.1	8.68	0.0052

36. ANALYSIS OF VARIANCE FOR CANOPY SIZE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rep	2	562404.6667	281202.3333	20.21	0.0022
treatment	3	246224.9167	82074.9722	5.90	0.0319

37. Estimated cost of production of maize and roselle

	BASIC COST OF PRODUCTION FOR THE EXPERIMENTAL AREA (576 m²)		**PER HECTARE (10,000m2)**	
No.	**ITEM/ OPERATION**	**UNIT COST (GHC)**	**TOTAL COST (GHC)**	**TOTAL COST GH**
1	PLOUGHING	5.76	5.76	100
2	HARROWING	4.32	4.32	75
3	SOWING	5.76	5.76	100
4	FIRST WEEDING	4.32	4.32	75
5	FERTILIZER (NPK)	28.8	28.8	500
6	FERTILIZER APPLICATION	5.76	5.76	100
7	FERTILIZER (SULPHATE OF AMMONIA)	12.24	12.24	212.5
8	FERTILIZER APPLICATION	5.76	5.76	100
9	COST OF PESTICIDES AND LABOUR	2.88	2.88	50
10	SECOND WEEDING	4.32	4.32	75
11	HARVESTING(MAIZE)	5.76	5.76	100
12	HARVESTING(OKRA)	10.8	10.8	187.5
13	DEHUSKING	5.76	5.76	100
14	SHELLING	5.76	5.76	100
15	ROSELLE SEEDS	5.76	5.76	100
16	MAIZE SEEDS	5.76	5.76	100
17	COST OF SACKS	5.76	5.76	100
18	COST OF TRANSPORTATION OF MAIZE	2.88	2.88	50
19	COST OF TRANSPORTATION OF ROSELLE	27	27	468.75
	TOTAL		**155.16**	**2693.75**

38. COST BENEFIT ANALYSIS

INTERCROP ARRANGEMENTS	YIELD OF MAIZE (KG)	MONETARY VALUE GHC	YIELD OF ROSELLE KG	TOTAL REVENUE	TOTAL REVENUE PER TREATMENT	PRODUCTION COST	PROFITABILITY	% PROFIT ACCRUED
1:1	1152.083333	2304.166667	15001	2250.15	4554.316667	**2693.75**	1860.566667	40.85281729
1:2	815.1041667	1630.208333	7321	1098.15	2728.358333	**2693.75**	34.60833333	1.268467302
2:1	1315.104167	2630.208333	14658	2198.7	4828.908333	**2693.75**	2135.158333	44.21617032
2:2	1685.416667	3370.833333	16979	2546.85	5917.683333	**2693.75**	3223.933333	54.47965279
SOLE MAIZE	1903.645834	3807.291669			3807.291669	**2693.75**	1113.541669	29.24760606
SOLE ROSELLE			21204	3180.6	3180.6	**2693.75**	486.85	15.30686034

ROSELLE

39. ANALYSIS OF VARIANCE FOR CALCIUM (CA)

Source	DF	SS	MS	F	P
TRT	4	0.96697	0.24174	0.48	0.7525
Error	10	5.07267	0.50727		
Total	14	6.03964			

40. ANALYSIS OF VARIANCE FOR COPPER (CU)

Source	DF	SS	MS	F	P
TRT	4	108.214	27.0536	0.85	0.5270
Error	10	319.640	31.9640		
Total	14	427.854			

41. ANALYSIS OF VARIANCE FOR MAGNESIUM (MG) Source DF SS MS F P

Source	DF	SS	MS	F	P
TRT	4	0.50209	0.12552	5.64	0.0122
Error	10	0.22247	0.02225		
Total	14	0.72456			

42. ANALYSIS OF VARIANCE FOR NITROGEN (N) Source DF SS MS F P

Source	DF	SS	MS	F	P
TRT	4	1.43689	0.35922	0.75	0.5828
Error	10	4.82020	0.48202		
Total	14	6.25709			

43. ANALYSIS OF VARIANCE FOR PHOSPHORUS (P) Source DF SS MS F P

Source	DF	SS	MS	F	P
TRT	4	0.06753	0.01688	0.63	0.6541
Error	10	0.26927	0.02693		
Total	14	0.33680			

44. ANALYSIS OF VARIANCE FOR LEAD (Pb) Source DF SS MS F P

Source	DF	SS	MS	F	P
TRT	4	1620.39	405.099	1.04	0.4322
Error	10	3882.12	388.212		
Total	14	5502.51			

45. ANALYSIS OF VARIANCE FOR ZINC (Zn) Source DF SS MS F P

Source	DF	SS	MS	F	P
TRT	4	1106340	276585	1.17	0.3811
Error	10	2367227	236723		
Total	14	3473567			

46. ANALYSIS OF VARIANCE FOR pH Source DF SS MS F P

TRT	4	3.5707	0.89267	1.11	0.4059
Error	10	8.0733	0.80733		
Total	14	11.6440			

47. ANALYSIS OF VARIANCE FOR TSS

Source	DF	SS	MS	F	P
TRT	4	2.95600	0.73900	2.68	0.0936
Error	10	2.75333	0.27533		
Total	14	5.70933			

48. ANALYSIS OF VARIANCE FOR TTA

Source	DF	SS	MS	F	P
TRT	4	0.29479	0.07370	0.31	0.8639
Error	10	2.36568	0.23657		
Total	14	2.66047			