EFFECTS OF INTERCROPPING COWPEAS WITH MAIZE AND PHOSPHOROUS LEVELS ON GROWTH AND YIELDS OF COWPEAS IN MERU COUNTY

BY

JOSHUA MARUBE OMUNDI

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DECLARATION AND RECOMMENDATION

This thesis is my original work and has not been presented for a degree or any other award in any other University.

Signed_________________ Date________________

Joshua Marube Omundi

REG. NO: AGR-3-0155-1/2013

This thesis has been submitted with our approval as University Supervisors.

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Signature………………………………………… Date………………………………..

Dr. Mugambi Mworia, PhD

Department of Agriculture and Natural Resources

Kenya Methodist University

Signature………………………………………… Date………………………………..

Dr. David Mushimiyimana, PhD

Department of Agriculture and Natural Resources

Kenya Methodist University

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DEDICATION

To my dear wife (Callen Ondara), daughters (Hopemary Kwamboka and Becky Nyabonyi) and son (Barack Kibogoto).

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ABSTRACT

Cowpea (Vigna unguiculata L. Walp) is a legume that is grown for various uses. It is consumed as grain, leaf for humans and as fodder by livestock with high nutritive value and high palatability. It is widely produced in sub-Saharan Africa as a source of income. It is drought tolerant and can suitably be used as an intercrop in an intercropping system. The attendant low yield of cowpea among smallholder farmers due to declining soil fertility has increased the need for site specific fertilizer recommendation. Land fragmentation and reduced arable land makes intercropping of cereals and legumes inevitable. A field experiment was conducted at Kianjai ward in Tigania West Sub County of Meru County during the March –May rain season of 2015 to investigate the effects of intercropping cowpeas with maize and four different levels of phosphorous on growth and yields of cowpeas. The treatments were sole cowpeas, sole maize, sole cowpeas planted with (0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg/ha SSP) and cowpeas intercropped with maize at (0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg /ha SSP).The design of the experiment was a Randomized Complete Block Design (RCBD) with four replicates. The experiment was monitored from March to July. The results show that plant heights at harvesting stage were significantly affected by both fertilizer levels and cropping system ($p<0.05$). The mean plant heights for 0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg/ha were 41.56 cm, 42.43 cm, 43.00 cm and 45.03 cm respectively. The number of branches were not significantly affected ($p>0.05$). The number of grains per pod were not significantly affected by cropping system ($p>0.05$) but were significantly affected by fertilizer level ($p<0.05$). The number of pods, grain weight and yields were significantly affected ($p<0.05$). Sole cowpeas recorded the highest number of pods, grain weight and yields. The mean grain yields for 0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg/ha were 400 kg, 496.88 kg, 593 kg and 699.88 kg respectively. The Land Equivalent Ratio was greater than one ($LER>1$) thus intercropping was beneficial. Intercropping cowpeas and maize at 75 kg/ha phosphorous gave the highest Land Equivalent Ratio (1.9305). It is hereby recommended that in a cowpeas-maize intercropping system application of 75 kg/ha should be adopted. More work to be done to determine effects of intercropping cowpeas with other cereal crops other than maize.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
ANOVA	Analysis of Variance
ATER	Area Time Equivalent Ratio
BNF	Biological Nitrogen Fixation
CEC	Cation Exchange Capacity
CGR	Crop Growth Rate
CS	Cropping System
DAS	Days after Sowing
FAO	Food Agricultural Organization
FL	Fertilizer Level
KALRO	Kenya Agricultural & Livestock Research Organization
KFSSG	Kenya Food Security Steering Group
LAI	Leaf Area Index
LER	Land Equivalent Ratio
LSD	Least Significance Difference
NAR	Net Assimilation Ratio
NH4	Ammonia
NUE	Nitrogen Use Efficiency
PEP	Physiological Efficiency of Phosphorous
PLER	Partial Land Equivalent Ratio
PRE	Phosphorous Recovery Efficiency
PUE	Phosphorous Use Efficiency

RCBD	Randomized Complete Block Design
SPSS	Statistical Package for Social Scientists
SSA	Sub Saharan Africa
SSP	Single Super Phosphate
TSP	Triple Super Phosphate
UM2	Upper Midland Two
USDA	United States Development Agency
WUE	Water Use Efficiency

CHAPTER ONE

INTRODUCTION

This chapter covers the background review of the study, problem statement and its subsequent justification. It also stipulates the general and specific objectives the study set out to find. It also outlines the research hypothesis.

1.1.Background of the Study

Cowpea (*Vigna unguiculata* L. Walp.) has an important role in the livelihood of millions of people especially in the developing world (FAO, 2002; El Naim & Jabereldar, 2010). Cowpea can be consumed as leaf and forage or grain because they both have high nutritive value and high palatability (Whitebread & Lawrence, 2006). It is also a cheap source of protein for consumers whom do not have the financial means to include animal proteins in their day to day diet and provides income to farmers (Nyoki & Ndakidemi, 2014).

Reports by FAO indicate that cowpea farming in Africa was done in approximately 12.3 million ha in the year 2014 and West African countries reporting bulk production from 10.6 million ha. Major producers include Mali, Nigeria, Niger, Burkina Faso, and Senegal (Food and Agriculture Organization of the United Nations Statistics Division [FAOSTAT], 2016). As per the report by the Kenyan ministry of Health in 2012, cowpea production acreage increased from 85,510 ha in 2006 to 115,800 ha in 2011; however, the average production of cowpea has remained between 0.2 - 0.5 t/ha. Owing to its capability to fix nitrogen in the atmosphere, it is suitable for improving fertility of the soil (Abayomi et al., 2008). Low cowpea yields in Tropical Africa can be attributed to many factors but lowered application of external inputs and low fertility of soil are the most pertinent (Harun et al., 2011).

Soil degradation is another key characteristic of most African tropical farmlands resulting to low levels of fertility and consequently reduced crop yields (Nyoki & Ndakidemi, 2014).

Majority of farming systems located in Sub-Saharan Africa (SSA) face the challenge of poor crop productivity (Chianu et al., 2010). Cowpea productivity in sub-Saharan African countries like Kenya is very low due to low input agriculture common amongst farmers. Continuous cropping without the use of either organic or in-organic fertilizers has been cited among the causes of deteriorating soil fertility (Odhiambo & Magandini, 2008). Low soil P is caused by continuous cultivation and nutrient depletion (Magani & Kuchinda, 2009). According to Pule et al. (2010), cowpea (*Vigna unguiculata* (L) Walp) is a legume that has gained widespread adoption by farmers across Sub-Saharan Africa making it one of the most farmed crop within the this region.

Poor financial status of farmers is a major constraint limiting farmers' utilization of inorganic fertilizer in tropical Africa despite low soil fertility. Regardless, several authors have reported a positive response of cowpea productivity and application of inorganic and organic fertilizers especially phosphorous based fertilizers (Nkaa et al., 2014). Famers have over the years used diverse cropping systems as a way of increasing crop productivity and guarantee sustainability. One preferred system is intercropping and it is defined as growing multiple crops in the same plot of land within the same season. The rationale for its preference is that it promotes crop interaction, maximizes productivity of the land, prevents dependence on one crop, and allows multiple crops to be farmed within the same plot of land (Thayamini & Brintha, 2010; Sullivan, 2003).

The main reason for intercropping is not only to increase productivity of land per unit area in a given time, but also to judiciously exploit farming inputs such as labor, as well as the available land resources. Intercropping legumes with maize, for instance, is considered an effective way of maximizing their overall productivity while at the same time securing nitrogen economy in levels that could not be achieved with a single crop system (Thayamini & Brintha, 2010).

According to Ijoyah and Fanen (2012), selecting individual crops to be grown together is an important consideration for any successful intercropping. Further reports indicate that factors which are likely to cause incompatibility such as planting density, competition for nutrients and density of roots need careful consideration (Ijoyah & Jimba, 2012). Since intercropping has proven to be a critical aspect in maximizing production of crops in both developed and developing economies (Adeoye et al., 2005), it is imperative that farmers consider compatibility of the crops they intend to intercrop because their productivity depends on land characteristics, lighting conditions, growth habits, and fertilizer utilization. Rather than planting any combination of a major and minor crop, (Thayamini & Brintha, 2010) assert the need for selecting compatible crops to maximize productivity.

The problem of soil fertility is not only an agronomic challenge, but also strongly attributed to social-economic factors. The constraint of soil fertility in poor farmlands can be ameliorated through intercropping. Findings made by Adeleke and Haruna (2012) show that usual practice of intercropping pulses with cereals enhances land productivity rather than addressing the challenges related to soil fertility. Reports have further indicated that combination of cowpea and maize has positive benefits on soils that are nitrogen poor (Vesterager et al., 2008).

Dahmardeh et al. (2010) found out that intercropping cowpeas and maize has the ability to increase phosphorous, nitrogen, and potassium levels as compared to having monocrop of maize. Amos et al. (2012) noted that soil fertility maintenance and improvement should not only rely on inorganic fertilizers, but also through other means such as intercropping. Intercropping systems have some challenges in relation to planting, fertilizer application and management, weeds and pest management, and harvesting. This is because these farm operations are done manually by farmers engaged in small-scale production (Sullivan, 2003).

1.2. Statement of the Problem

Land fragmentation and reduced arable land makes intercropping of cereals and legumes inevitable. This coupled with declining soil fertility have led to cowpeas yields persistently remaining low thus compromising food security and therefore exposing millions to risk of hunger. There exists an insufficiency of essential nutrients particularly N and P in majority of soils in the tropics. This compels cowpeas farmers to apply inorganic basal fertilizers every season to sustain production and meet their subsistence and market requirements. Among the solutions towards reducing low yields due to low levels of P in the soil is determination of the best level of P application to maximise returns from cowpea and yield.

However application of phosphorous and nitrogen based fertilizers is not effective because cowpeas do not respond to them. Only manure or dry compost should be applied at the recommended rate of 5 tons/ha where soils are highly eroded (Ministry of Agriculture, Field technical handbook, 2002). This information conflicts with what KALRO recommends that cowpeas be planted using SSP or TSP as the preferred basal fertilizer with a rate of application of 20-25 kg per hectare in a mono cropping system. This general recommendation may however not be suitable in an intercropping system. In Tigania West sub-county, farmers have been intercropping cowpeas with maize without adequate information on the effects it has on growth and yields and whether inorganic phosphorous is necessary. This study is geared towards determining the effects of intercropping cowpea with maize and phosphorous levels in Tigania West Sub County.

1.3. Justification

Small-scale farmers residing in Meru County have traditionally practiced intercropping for decades. Specifically, legumes and cereals are recognized as the common cropping system being applied throughout tropical developing countries. Wide ranging seed yields from cowpeas have been documented though they are largely low. For years Africa has lagged behind its population growth in terms of food production despite a consistent increase in demand for livestock products. This has been compounded by stresses originating from climate change hence the need for seeking a perfect crop. In this case, cowpea suits the bill.

Soil fertility used to be maintained through fallow arrangement in traditional African societies. However, intensive cropping in Kenya has systematically replaced the traditional shifting agriculture that is reminiscent of fallow arrangement hence notable decrease in crop yields. This continued decline in food production has prompted farmers to modify their soils using inorganic and organic materials with an aim of improving crop yield and plant growth. Cowpea growers have been advised to use organic manure instead of chemical fertilizers to mitigate their long-term negative effects on the soil such as increased acidity levels. However availability of these materials is a challenge besides their bulk nature and large amounts required.

1.4. General Objective

The overall objective is to find out the effects of intercropping cowpeas with maize (H 513) and phosphorous levels on growth and yields of cowpeas (M 66) in Tigania West Sub County.

1.5. Specific Objectives

i. To evaluate the effects of intercropping cowpeas with maize on growth and yields of cowpeas.

ii. To evaluate the response of cowpeas to four levels of phosphorous.

1.6. Research Hypothesis

i. There is a statistically significant difference in growth and grain yields of cowpeas when intercropped with maize.

ii. There is a statistically significant difference in growth and grain yields of cowpeas when planted at various levels of phosphorous.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews the available literature on status of food security in Kenya, cowpeas description, ecological requirements and production, soil fertility and intercropping systems as documented by various researchers**.**

2.1. Food Security in Kenya

Kenya relies mainly on the agricultural sector to guarantee that there is food security and meet the requirements of her population. In this case, food security is defined as the situation where every person has social, economic and physical access to nutritious and safe food in sufficient quantities. In addition, the accessed food must have the capacity to meet their preferred dietary needs required for their healthy and active lifestyles (Kenya Food Security Steering Group, 2008). Over the years Kenya has faced severe food shortages and food insecurity difficulties as portrayed by the large proportion of its population without access to appropriate quality and quantity of food. Reports have estimated that more than 10 million people are facing difficulties in accessing quality food in the recommended quantities forcing a sizeable portion of the population to depend on food aid/relief food.

In addition it is estimated that 40% of the households' in Kenya are food insecure throughout the year (FAO, 2008). There is a worrying trend of increased cereal importation so as to bridge the food deficit in Kenya (FAO, 2008). Households are forced to spend huge portions of their income on food since prices are high. The supply of maize despite being Kenya's staple food is below requirements. Several factors are responsible for the current food insecurity challenges including drought and high cost of farm inputs. Furthermore 75% of the rural house-holds are engaged in unproductive low input/low output subsistence farming (Kelly et al., 2003).

2.2. Cowpeas Production and Challenges

FAO reports indicate that cowpea crop was farmed on approximately 12.3 million ha in Africa in the year 2014 and West African countries reporting bulk production from 10.6 million ha. Major producers include Burkina Faso, Niger, Senegal, Mali and Nigeria (Food and Agriculture Organization of the United Nations Statistics Division [FAOSTAT], 2016).In Kenya, a report from the Ministry of agriculture in (2012) indicates that the area under cowpea production increased from 85,510 ha in 2006 to 115,800 ha in 2011 but the average production stands at between 0.2 - 0.5 tons/ha as compared to the expected average of 0.8-1.8 tons/ha for most varieties(Karanja et al., 2008).

The low production of cereals and legumes among small-scale farmers in Kenya can be attributed to the decreasing soil fertility resulting from many years of incessant cropping practices with little or no additional soil fertility amelioration technologies. Nitrogen (N) and Phosphorous (P) form part of the nutrients that are considered as most limiting (Kipkoech et al., 2010). Majority of famers in Kenya, just like their peers in Africa, can rarely afford external inputs. Therefore the most appropriate technologies for these farmers are those that require them to manipulate existing and affordable technologies to improve crop production.

Low soil fertility forms one of the key challenges facing cowpea production, especially in the sub-Saharan region of Africa. Most smallholder farming systems face the challenge of soil fertility management because they have extracted significant quantities of nutrients over decades without applying sufficient quantities of fertilizers for their replenishment. This trend has resulted into an average rate of annual depletion of approximately 2.5 kg of phosphorous, 22 kg of Nitrogen, and 15 kg of potassium for every hectare of land farmed within 37 countries across Africa over three decades (Koohafkan & Altieri, 2010). Majority of small holder farmers have therefore resorted into application of costly chemical fertilizers as a means of overcoming the challenge of nutrient depletion.

There are several insect pests that have been known to attack cowpea (Gungula & Garjila, 2005). Some of the flowering and post-flowering insect pests are flower thrips, blister beetles, maruca pod borer, and pod-sucking bugs (Oyewale & Bamaiyi, 2013). These pests severely attack the crop at every developmental stage, which makes it imperative to use the tolerant varieties and insecticide sprays. In circumstances where cowpea fields are infested by post-flowering insect pests thereby causing damage to grain yield, farmers especially the ones living in semi-arid and arid regions, tend to utilize their crop as fodder in order to generate some income.

However, cost benefit analyses indicate that farmers get more financial benefit from cowpea grain as compared to utilizing it for fodder. If grain yield is to be obtained, farmers are obliged to spray cowpea field with insecticides two to three times during growing period. In the recent years, progress has been made through genetic improvement whereby disease and pest resistance genes have been incorporated into new cowpea varieties (Dzemo et al., 2010). Through breeding programmes some traditional varieties have been improved by introducing into them simple inherited resistance genes. This scientific progress has enabled farmers to obtain high grain yield with little investment in chemical use. Regrettably, no cowpea line has been found to possess adequate levels of resistance to bugs that suck their pods (Riptortus dentipes, Clavigralla tomentosicollis and Anoplocnemis curvipes), all of which are post-flowering pests (Oyewale & Bamaiyi, 2013). There has been a growing interest in research to come up with eco-friendly and sustainable agricultural technologies that could help in overcoming some of these challenges (Malusá et al., 2012).

Table 2.1

National Production Trend of Cowpea t /ha (2006-2011)

Year	Hectares	Production
2006	85,510	17,102
2007	102,882	48,212
2008	82,784	68,363
2009	91,452	27,808
2010	102,900	45,872
2011	115,800	50,679

Source: Ministry of Agriculture Economic Review planning Division (2012)

Cowpea Ecological Requirements

Cowpea is among the legumes considered to be the most heat and drought tolerant growing in areas with only 500 mm rainfall per annum. The longer podded varieties require high rainfall of up to 1500 mm per annum. Although cowpeas grow on wide ranging types of soil, this crop has shown preference for sandy soils because they are less restrictive on growth of roots. Cowpeas also grow the best in summer at an optimum temperature of 8.5 °C for germination and 20 °C for leaf growth. This shows that cowpea is a heat loving crop and the optimal temperature required for growth is approximately 30°C.

Some Cowpea Varieties Grown in Kenya

Machakos 66

The cowpeas M 66 (Machakos 66) variety was developed by KALRO researchers in Machakos. M 66 is a semi-spreading and bushy plant that has indeterminate growth habits. With a maturity of 80-90 days, it is normally grown for both grain and leaves. In addition to having dark green leaves and midrib, it has purple flowers with white corolla. The flowers bloom between 55 and 60 days. Its pods have been observed as green when young, after that they turn bright red when filling grain, and finally purple when they dry. The seeds become creamy brown with a small eye. The overall yield from this variety is between 800 and 1700 kg/ha. The tolerance of M 66 to scab and yellow mottle is high. However its tolerance to powdery mildew and septoria leaf spot is moderate. In addition, it has some level of field tolerance to thrips and aphids since it may undergo mutation during its growing period.

Katumani 80

This variety of cowpea is dual-purpose since it can be used for both grain and leaf production. Among its key characteristics is the semi spreading habit and presence of elongated leaves that have distinctive silvery midribs. Its flowers are primarily purple but the corolla have whitish pigment that has been defined as ivory 10. In addition, seeds are green while immature but turn white brown with interspersed faint spots of brown. The variety has shown to be resistant aphids, moderate tolerance to thrips, leafhopper, and pod borers, fungal diseases, and mosaic virus. Its overall yield is recorded at 800 to 1800 kg/ha.

Ken Kunde 1 (KK1)

This is a dual-purpose variety of cowpea and it takes 75-90 days to fully mature. Its special attributes is its drought resistance and ability to grow efficiently in wide ranging types of soils (Karanja et al., 2008).

Kunde Mboga

This variety, which ideally does well in warm climates, takes 30-45 days to mature. It is a local vegetable with soft dark green leaves. On investment, it has a very high return. Its harvesting period is very long. A major advantage or special attribute of this variety is the fact that it aids in restoring soil fertility.

KVU 27-1

This is another dual purpose variety of cowpeas that can be cultivated for its leaf and grain. It has a notable semi-spreading habit coupled with indeterminate flowering pattern, pointed leaves, flowers that are blue, and grains that have dark red color. This variety has demonstrated moderate tolerance to aphids, thrips, pod borers, leaf hoppers, foliar fungal disease and mosaic virus. The overall yield from this variety ranges between 800 and 1700 kg/ha.

Cowpea Cultivation and Management

Cowpea can be grown either in pure stand or in a mixed environment together with other crops like maize. They are cultivated from seeds through either broadcasting under mixed cropping or sown in rows 2.5 cm deep in, with a spacing of 30 cm in case of mono cropping and 40 cm apart with an inter crop (Ruto,2008). Seed rates when broadcasted is 50-60 kg/ha and 30-40 kg/ha when grown in pure stands. Cowpea which is produced for fodder, cover crop or as green manure is supposed to be planted at a higher seed rate ranging from 90-100 kg/ha (Ruto, 2008). According to Nzabi (2000), the ability to have a deep root system in conjunction with earliness in maturity are among the notable traits that enable cowpea to get adapted to hostile environment. Like other legumes, cowpea is known to form synergetic relationships with specific bacteria residing in the soil (Rhizobium spp), and fixes nitrogen in the soil (Ruto, 2008). Inoculation with N-fixing bacteria is beneficial in instances where production of cowpeas is in areas where it has not been grown recently. Time from planting to harvesting varies from 3 months for fast maturing varieties to 5 months for slower ones.

The crop is usually hand-harvested. The leaves and pods are picked at frequent intervals as, and when they mature. On average, yields of dry leaves of cowpea ranging from 240 kg/ha to 400 kg/ha has been documented (USDA, 1995). Average grain yield of dry cowpea under subsistence agriculture is recorded at 100-500 kg/ha. Yet yield potential of 3 t/ha and 4 t/ha of leaves under good management can be attained (USDA, 1995).

Supply of cowpea is determined by the yield obtained per season. According to the Ministry of Agriculture report (2012), the area under cowpea production has progressively increased from 85,510 ha in 2006 to 115,800 ha in 2011. However, the average grain yields have remained low at between 0.2 t/ha-0.5 t/ha. This probably is as a consequence of lack of enough farm inputs, poorly managed soil fertility and bad agronomic practices. The use of appropriate rates of fertilizer, inoculation of certified seeds and appropriate cropping system can achieve a higher yield**.**

2.3. Soil Fertility

The definition of soil fertility is the capacity of the soil to cycle, retain, and supply the necessary nutrients to support growth of plants for prolonged periods of time (Alley & Vanlauwe, 2009). The abundance of nutrients in the soil is very important in crop production since the soil is the main source of plants nutrients. Lowered fertility of the soil, mainly N and P deficiencies, is one of the major biophysical limitations impacting agriculture in Africa. The implication of this is that all other efforts and strategies geared towards addressing food production and security will bear no fruits unless mechanisms are put in place to address depletion of soil fertility. Diminishing soil fertility has become a major impediment towards attainment of consistent agricultural growth, as well as the main cause of the slowed food production capability by smallholder farmers residing in the Sub-Saharan parts of Africa (Rutto et al., 2006).

Sub-Saharan part of Africa (SSA) is the world leader when it comes to soil degradation and most soils are inherently low in plant nutrients. Studies have shown that nitrogen is a nutrient whose availability controls the rate of plant growth and soils lacking sufficient amounts of this nutrient have low yields especially within the tropics (Bationo et al., 2008). Reduced soil fertility is a major biophysical factor that causes low crop yields thus compromising food security particularly for farmers engaging in small scale farming operations. Available statistics indicate an annual loss of soil nutrients in Kenya at an average of 3 kg P, 42 kg N and 29 kg K ha-1 (Njeru et al., 2015). This is one of highest in Africa.

Soil Fertility Improvement

Land fragmentation and intensive cultivation have made use of fertilizers inevitable in order to achieve and maintain high crop yields. Continuous application of inorganic fertilizers is not helpful in soil fertility amelioration since in the long run it results to high levels of soil fertility and nutrient imbalance (Ondieki et al., 2011). Furthermore according to Kipkoech et al. (2010), these fertilizers are usually not easily accessible owing to their high cost thus unaffordable to majority of farmers with little incomes. Use of organic manures, such as poultry manure, cow dung, and crop residues can be substituted for the inorganic fertilizers to lessen the acidity levels in the soil. There is renewed interest in the use of energy sources that are renewable and their preference has revived the use of organic fertilizers globally.

Application of organic manures in adequate amounts sustains crop production systems through efficient recycling of nutrients (Agbede et al., 2008). Nutrients found in organic manures are usually released slowly and stay longer in the soil, thus guaranteeing prolonged residual effects that are essential for good root development, which translates to higher crop yields (Suge et al., 2011). Concerns on environmental degradation and public health coupled with need to reduce the high costs of inorganic fertilizers are key arguments when advocating for increased utilization of organics. Suge et al. (2011) reported that applying organic manures plays a main role in good plant growth. Organic manure contains all essential micronutrients and macronutrients in available forms during mineralization resulting to improvement of both the biological and the physical properties of the soil.

Further, Ayoola and Makinde (2009) found out that manures that are organic usually decompose and yield humus that play a critical part in influencing the chemical behavior of various metals in soil through its humic and flavonic acid content, for they have the capacity to preserve these metals in their chelate and complex forms reducing their toxicities. These materials too have the ability to decrease the P absorption capacity of soil; solubilize P from insoluble Ca, Fe and Al phosphate thus increasing P available for plant uptake (Agbede et al., 2008).

Besides enhancing P availability, organic materials supply other necessary nutrients especially N because their tissues have high concentrations of nitrogen (Agbede et al., 2008). In addition these materials release carbon to the soil hence providing substrate for microbial growth and other activities. The soil pH and subsequent nutrient availability is to a greater degree influenced by addition of organic manure. Organic manures have the ability to improve soil structure, its ability to hold water, and the resultant soil aeration. Nevertheless in the humid tropics the benefits obtained from utilization of organics have not yet been realized fully (Ayoola et al., 2009). In fact, large quantities of organic fertilizers are required so as to meet the expected amounts of nutrients required by individual crops. Additionally nutrients release from these organic materials can be improved by combining them with inorganic components with a fast release rate so that they can quickly supply nutrients before the slower organic materials begin releasing their contents.

2.4 Effect of Phosphorus on Growth of Cowpea

Phosphorus is one of the seventeen nutrients that are considered essential for optimal growth and development of plants. It is a macronutrient that can limit growth and productivity when not available in the required quantities. Crops require adequate amounts of this nutrient for them to produce maximum yield. Cowpeas require large amounts of P because it helps in root development and energy transfer through photosynthesis. It is necessary during flower initiation, delayed physiological maturity, plant growth, improved N fixation and utilization through enhanced nodulation. An inadequate level of P is the greatest impediment in agricultural production systems (Lynch & Brown, 2008). Crops can only absorb nutrients available in the soil solution and P is absorbed in form of phosphate ions.

Phosphate ions in the soil can readily react and become part of the soil particle. It has been reported that P is required in large amounts by leguminous plants not only for growth but also in promoting biomass, leaf area, grain yield, and mass of nodules (Wakeel et al., 2011). Phosphorous is also involved in numerous key enzymatic reactions that involve phosphorylation. Phosphorous is very essential for development of meristem tissue and in the process of cell division. Symbiotic fixation of nitrogen also requires higher P amounts for maximum activity as compared to growth that is supported by assimilation of nitrate. This is attributed to the high amounts of energy required to reduce atmospheric nitrogen by the enzyme nitrogenase.

Through determination of nodule functioning and development, plant requirement for P can be calculated as it pertains to their optimal nitrogen fixation processes and growth. Findings by Owolade et al. (2006) have indicated that phosphorus is an important component in the process of symbiotic N fixation by enhancing root development; lessening the time required by developing nodules to get activated and become beneficial to their host legume. In addition it is involved in the process where the size and number of nodules are increased, as well as the resulting amount of N that is assimilated per unit weight of the same nodules. This on the other hand increases the proportion and total sum of N in the portion of the harvested host legume and enhances Rhizobia bacteria concentration in the soil surrounding the root.

In the ranking of essential plant nutrients, phosphorous seconds nitrogen as an elemental mineral requisite for sustainable crop production. However, P exists as poorly soluble mineral phosphate that is unavailable for use by plants (Marschner, 2012). Therefore, there is need to provide high amounts of phosphorous since crops need it for nitrogen fixation and nodulation. In cases where legumes depend on symbiotic nitrogen as a source of N and receive low levels of phosphorus, they are likely to experience deficiency of nitrogen due to their inability to fix nitrogen (Weisany et al., 2013). KALRO recommends an application of 20-25 kg /ha of either Single Super Phosphate (SSP) or Triple Super Phosphate (TSP) (Karanja et al., 2008) in growing cowpeas as pure stand.

Low Soil P Conditions and Impact on Cowpea Production

Land degradation and low levels of soil fertility are the major reasons for the existence of low agricultural productivity, which in turn translates to food insecurity worldwide. The major challenge facing small holder farmers in crop production is inadequate levels of essential nutrients such as P and N in most soils. The problem of inadequate phosphorous often results from soil erosion, P removal in harvested crops and depletion of P through continuous cultivation. According to Zhu and Lynch (2004), low P availability in soils affects root traits that include lateral root branching, density of the roots, and length of root hairs and also parenchyma formation. Additionally, it also affects the root morphology, delays root emergence in crops, and reduces root hair numbers and physiological characteristics that are associated with P uptake.

Low levels of P in common bean has been reported to stimulate shallower basal root growth angles, increased adventitious root production and overall, promotes shallow root systems for P-efficient genotypes. Inadequate amounts of P in plant shoots has been described to result into decreased photosynthesis and stomatal conductance and consequently results in restricted plant growth (Ghannoum & Conroy, 2007). The challenge of having P deficiency in soil can be addressed through application of fertilizers that have concentrated nutrients so as to provide adequate soluble inorganic P (Pi) for the plant (Lynch & Brown, 2008).

Mechanisms for Plant Adaptation to Low P Condition in the Soil

Plants have developed adaptive mechanisms relating to their physiological, morphological, and biochemical systems in order to allow them respond to P insufficiency (Suriyagoda et al., 2010). Plant morphological mechanisms to deal with insufficient P in soil include prolific root development such as finer roots, higher root: shoot ratios, longer root hairs and development of arbuscular mycorrhizas. All these aspects improve the ability of plants to explore greater soil volume. The primary purpose of roots is their ability to extract P from the soil (Niu et al., 2012). Mechanisms that promote acquisition of P from the soil include soil-P mobilization through root exudates, symbioses with soil microbes such as vesicular-arbuscular mycorrhiza and enriched root growth and activity.

Mycorrihizae are the important type of arbuscular mycorrhiza fungi used in agricultural crops (Smith & Read, 2008). Root exudates play an important role that is maintenance the contact between the root and soil, which is critically important for plants under drought conditions, when hydraulic continuity is minimal. According to Atemkeng et al (2011), mechanisms for phosphorous uptake by plants include genetic variation among crop species. The existence of genetic variation for P efficiency makes it possible for agricultural scientists to develop crop genotypes with superior adaptation to soils inherently low in phosphorous (Atemkeng et al., 2011).

Phosphorus use efficiency

The cultivation of legumes around the tropics usually occur in soils that have low amounts of P due to occurrence of processes that include erosion, weathering, and P fixation (Wang et al., 2010). This consequently makes low availability of P as a main hindrance of legume production in the tropics. As discussed by Fageria et al. (2008) plants are said to be nutrient efficient whenever they gain the ability to provide higher yields for every unit of nutrient used as compared to other similar plants growing under comparable agro-ecological conditions.

Phosphorus use efficiency (PUE), Phosphorus utilization efficiency (PUtE) and Phosphorus uptake efficiency (PUpE) are among the major agronomic indices that have been used to describe efficiency of phosphorus fertilizer as a source of nutrient.

According to Mosier et al. (2004), phosphorous use efficiency (PUE) or agronomic efficiency of phosphorus (AEP) is the yield of a crop in (kg) per kg of P nutrient applied. It is an efficiency index which gives an indication of the increase in productivity that is gained by using a particular nutrient. Phosphorus uptake efficiency or Phosphorous recovery efficiency (PRE) is the amount of nutrient (kg) in harvested crop per every kg of nutrient applied. This efficiency index gives an indication of the amount of nutrient that is removed from the system vis a vis the nutrient input to the same system. Phosphorus utilization efficiency or physiological efficiency of phosphorus (PEP) is the yield (kg) per kg nutrient taken up by the plant. This gives an indication of the efficiency at which P taken up by the plant is utilized for producing economic yield.

All these fertilizer use efficiency indices increase with a reduction in the amount of fertilizer applied even to levels well below optimum economic levels (Mosieret al., 2004). This scenario might tempt one to falsely conclude that application of the lowest fertilizer rates results in the most efficient cropping system while this is not the case. Monitoring the efficiency at which phosphorous fertilizer is used in legumes is fundamental for optimizing the available amount of P that is present for plant growth, and simultaneously minimizing the impact of applying P fertilizer on the environment. This is especially very important for P fertilizers that are water soluble as they form a majority of P fertilizers used for crop cultivation in the world (Chien et al., 2012).

Phosphorus recovery efficiency from soils varies and depends on the method used. According to Chien et al (2011), recovery of p fertilizer ranges from 10 to 25 %. The recovery of phosphorous fertilizer as far as this method is applicable can however be lower or higher depending on factors such as the rate of P fertilizer applied, available P level in the soil, and P sorption capacity of the soil. Soils with relatively high P sorption capacity will have almost 0% P fertilizer recovery for low rates of P applied due to sorption of P on soil surfaces while the recovery could be much higher than 25% in soils with low P sorption capacity.

Studies by Wang et al. (2010) indicate presence of genetic variability in plant P efficiency and P efficient plants have several adaptive mechanisms by which they are able to grow well even in soils containing low P. Some of these mechanisms include slight changes in root morphology and architecture, secretion of phosphatases and organic acids into the rhizosphere and symbiosis which is associated with the root. In case of soybean, root architecture and morphology, root exudates and root symbiosis have been found to be the most important traits for efficient uptake of phosphorous. Studies by Shah et al. (2001) that examine P use efficiency of soybean crop in relation to inoculation and application of phosphorous conclude that inoculation increases PUpE and PUE of the soybean but application of P fertilizer is associated with reduced PUE. The study also establishes that application and inoculation of P affect soybean yields through their documented effects on PUE.

While studying on cowpea Sanginga and Woomer (2009) reported that P use efficiency decreased with increasing P application. In contrast to PUE, PUpE however increased with the amount of P applied. Other yield variables such as dry matter production, ratio of shoot to root, total N in the shoot and amount of N fixed were strongly related to P uptake efficiency. Nitrogen efficiency is about 50% or lower with that of phosphorus varying between 10 – 30 % while that of potassium is between 20 – 40%. There are three ways that plants can use to improve their access to both native and applied soil P. These include, increasing their absorptive areas, favorable modification of absorption to increase uptake from low nutrient concentrations and modification of the rhizosphere to increase availability of nutrients. Plant genotypes that are P efficient are able to adjust their shoot to root ratio under different P levels. Some of these plants are capable of investing more energy in proliferation of their root biomass to increase the area in contact with soil root during P stress. Use efficiency of applied fertilizer varies depending on the type fertilizer nutrient.

2.5. Intercropping System

Intercropping has become a common agricultural undertaking among small holder farmers where they plant multiple crops at the same time of year in the same piece of land. According to Seran and Brintha (2010) the common combination of crops involves legumes and cereals. Classic example of intercropping combinations include maize – cowpea, Maize – soybean, millet-groundnuts, maize – groundnuts, as well as rice – pulses (Matusso et al., 2012). This decade old practice is widespread throughout the warmer climates of the world although it has gained little attention from researchers. However, there has been an increase in effort by agricultural scientists in intercropping system as a viable method of crop production.

Research work by some scientists on cereal- legume intercropping (Egbe et al., 2010; Ijoyah, 2012) have shown that intercropping is more beneficial as compared to single cropping. This system enables farmers to leverage on region specific agro-climatic conditions to improve production. Intercropping can be subdivided into four classifications based on practical spatial arrangements.

These are:

i. Row intercropping: this is a spatial arrangement where two or more crops are planted simultaneously with every crop occupying a distinctive row.

ii. Strip intercropping: in this arrangement, crops are grown together in strips that are wide enough to accommodate disparate crop production techniques that use machines; but, they are close enough for crops to interact. Mixed intercropping: production of two or more crops together without any distinct row arrangement.

iii. Relay intercropping: this is an intercropping technique where a second crop is planted in an already existing first crop. The first crop is usually at its reproductive stage but has not reached its harvesting stage.

Farmers with limited resources practice intercropping because they lack large amounts of farming land, and, to leverage on beneficial interactions associated with chemical application. Crops planted solely demand more chemicals to control diseases and pests. Sometimes, chemicals (pesticides, herbicides and insecticides) are not readily available despite the farmers having the necessary financial resources to acquire them.

An intercropping system makes very efficient utilization of the available nutrients and water resources; optimizes use of growth factors by efficiently capturing and using radiant energy (Matusso et al., 2012); improves and maintains soil fertility; prevents pests and diseases; and also suppresses weeds (Sanginga & Woomer, 2009; Seran & brintha, 2010). Such systems of cropping can be defined in reference to the temporal and spatial arrangement of different crops as a means of increasing productivity per unit of land, per unit time through efficient exploitation of natural resources (Gurigbal, 2010). Further, spatial arrangement facilitates the process of optimizing utilization of soil moisture, land, solar radiation, and nutrients. This is achieved through choice of appropriate crops with varying morphological and physiological characteristics, as well as optimally planned planting geometry to prevent competition for mutual resources while enhancing their complementarity to maximize overall productivity as in the case of intercropping.

2.6.Major Factors to be considered in Cereal-Legume Intercropping System

Several considerations are supposed to be deliberated before and during cultivation in order to realize a successful intercropping system (Seran & Brintha, 2010). For instance, the potential of an intercropped cereal-legume system to provide nitrogen is dependent on crop density, light interception, crop species and available nutrients. Importantly, choosing compatible crops is determined by land, light, plant growth habits, fertilizer use, and water (Brintha & Seran, 2009).

Duration to maturity

Enhanced crop interaction and greatest yield advantages take place when the intercrops experience different periods of growth because they make their major resource requirements at different durations. Consequently those crops with disparate maturity times have separate peak periods of maximum nutrients and light demand could form suitable components for intercropping. For example, Reddy and Reddi (2007) found out that in an intercropping system comprised of maize and green grams, the peak demand for light from maize peaked at 60 days from the day of sowing: at this time, green grams were ready for harvest.

Compatibility It is important to adopt the right combination of intercrops in any mixed cropping system so as to minimize plant competition. This can not only be achieved through a spatial arrangement, but also by a combination of crops that can best exploit soil nutrients. Production of cereals and legumes make an optimal combination because they exploit different nitrogen sources, which is scarce in most soils in SSA (Mugwe et al., 2011). Though the cereal may be more competitive in comparison to the legume in regard to absorption and utilization of N, legumes have the ability to fix N as long as there is an effective strain of Rhizobium.

It is important to observe that some intercrop combinations pose negative impacts on the yield of individual components growing under an intercropping system. For instance Mucuna (*Mucuna utilis*) when planted together with maize results to a decline in maize yields. Cowpeas and green gram have lower implication on maize production and besides they can tolerate maize shade. Odendo et al. (2011) reported that intercropping maize and beans is common in Eastern part of Africa, whereas in Southern Africa, maize is commonly cultivated together with bamabara nuts, cowpeas, and groundnuts.

Plant density. It is a normal recommendation that seedling rate of every crop in intercropping is lower than its full rate in case of sole cropping in order to maximize the density of plants. Adopting a full rate of every crop would result to reduced yield due to overpopulation (Seran & Brintha, 2010). In fact, an increase in population of bean plants results into lowered dry yield accumulation of maize plants. Muoneke et al. (2007) reported that an increase in maize seed rate reduced soybean grain yield by 21 and 23 percent when maize population was 44,440 and 53,330 plants/ha, respectively, compared with 38,000 maize plants/ha. Egbe (2010) reported that competitive ratio is directly related to the population of soybean; whereby, it increases by 0.76 - 1.15. this is indicative that higher densities have higher competitiveness although sorghum has shown an opposite trend at 1.23 - 0.76.

Time of planting. Numerous studies have been conducted to investigate the effect of time of planting in relation to performance of the different intercrop components. In the study by Barbosa et al. (2008) maize and cowpea intercrop where maize is planted early gives impressive results. This can be attributed to the cowpea controlling weeds. Moreover, research has found that maize intercropped with soybean at the same time has higher value of growth rate (CGR), leaf area index (LAI), and net assimilation rate (NAR) in comparison with maize that had been grown later after soybean (Addo-Quaye et al., 2011)**.**

Resource Use in Intercropping

Intercropping systems, according to (Flores-Sanchez et al., 2013), have the capacity to increase temporal and spatial uptake of nutrients. Undie et al. (2012) further assert that temporal advantage during uptake of nutrients is achieved when crops within an intercropping system reach their peak nutrient requirements at differing times (Matusso et al., 2012). In the case where cereals and legumes are intercropped, there is more efficient use of nutrients due to their differing uptake and root patterns (Seran & Brintha, 2010; Undie et al., 2012; Flores-Sanchez et al., 2013).

On the other hand intercrops with root orientations that are alike have a tendency of competing for resources at the same surface level (Hamidou et al., 2013). A common practice occurring in tropical agriculture has been intercropping of low and high canopy crops. Energy for photosynthesis is derived from solar radiation, which eventually determines water use by processes of transpiration and evaporation, as well as productivity potential of the crops. Intercrop spacing should be sufficiently wide to allow for efficient light interception (Seran & Brintha, 2010). It is not possible to store solar radiation for later use; therefore, it has to be intercepted and used instantaneously to give energy to the process of photosynthesis.

Research findings by Jiao et al. (2008) indicate that intercropping enables maize to efficiently use strong radiation and grounds nuts to efficiently use weak light resulting in higher yields. Different intercrop canopies due to variation of planting geometry, time when planting, plant orientation, spatial distribution, and leaf size influence plant growth and productivity. On the other hand, growth of plants in any intercropping system depends on water availability and efficient use of other related resources (Dahmardeh et al., 2010). There is an increase of up to 7% of water utilization, as well as interspecific competition among intercrops thus the recommendation that a delay of four weeks be observed when intercropping roselle and maize crops (Flores-Sanchez et al., 2013).

2.7.Benefits and Challenges of Intercropping

The main reasons for farmers to adopt an intercropping system include flexibility, maximization of profits, and reduction of risk against possibility of crop failure, maintenance and preservation of soil, suppression of weeds and balanced nutrition. Legumes and cereals is a common combination among farmers because legumes raise soil fertility while combating erosion

(Matusso et al., 2012). Secondly, this combination has proven to give higher yields, provide yield stability, and efficiently use nutrients as compared to singular crops (Seran & Brintha, 2010). Probably this phenomena is due to lessened intra-specific competition, efficient use of the available environmental resources, greater yield stability, better control of weeds, improved quality of seeds, and access to insurance services against crop failure. For instance, when maize is farmed solely, it requires a large area to give the same yield as maize planted in an intercrop system.

When crops are grown individually they, they have a tendency of attracting diseases and pests that cause more damage in monocultures and lesser destruction in intercropped systems. The rationale for such disparate effect is due to microenvironment effects that are associated with intercropped conditions as compared to mono cropping practices. For instance, intercropping cowpea cultivar PAN 311 significantly reduces infestation of stalk borer in sorghum as compared to when it is farmed as a single crop (Ayisi & Mposi, 2001). Maize stem borer was found to be more severe under mono cropping than when maize is intercropped with lablab [Lablab purpureus (L)] (Maluleke et al., 2005).

Similarly there is improvement of quality through variety of crops and better control of weeds without necessarily using large area of land to harvest similar yield as in an intercropped system (Ijoyah, 2012). When cowpeas and cereals are intercropped, there is significant reduction of striga infestation because cowpea provides soil cover that creates unfavorable environment for striga development (Musambasi et al., 2002). The system also ensures a better means of distributing labour and at the same time providing a more balanced supply of food to humans.

Although intercropping is advantageous in production of cereal crops, it accelerates nutrient depletion, especially phosphorous, due to efficient utilisation of soil nutrients (Mucheru-Muna et al., 2010). Intercropped plants become competitive when they share common growth factors which are significantly below their combined demands within the same environment (Thole, 2007). Agronomic features like sowing time, application of fertilizer and proportions of crop mixtures in combination with morpho-physiological changes determine the intensity of competition among crops. In the case where arrangement of crops is in rows, the intensity of competition is measured through duration of growth, comparative growth rates, and proximity of roots.

Cereals in a legume-cereal intercrop has height advantage, more widespread rooting system, and advanced growth rate that gives them comparative advantage in competition with legumes. Intercropping has a major drawback in that it is not well adapted to poorly drained and heavy clay soils. In addition, the yield component may reduce because of intense competition (Thole, 2007). It also poses difficulties in harvesting especially where use of machinery is involved. Mechanical operations that include weeding, sowing, harvesting, and fertilising are very difficult due to lack of uniformity in the farmed lands. Although there are instances where modern machines have been used in intercropped systems, large scale intercropping has proven almost impossible.

2.8.Resource Use in Intercropping

In the research by Flores-Sanchez et al. (2013) intercropping systems are capable of allowing both temporal and spatial increases in overall nutrient uptake. According to Undie et al. (2012), temporal advantage can be experienced when crop uptake of nutrients in an intercrop system peak at different times. Additionally, plants with differing uptake and root patterns such as legumes and cereals have higher efficiency in using the available nutrients (Matusso et al., 2012), as well as higher uptake of nitrogen (Seran & Brintha, 2010; Undie et al., 2012; Flores-Sanchez et al., 2013). Since intercropping plants with similar root orientations compete for nutrients at the same surface level, intercropping of high and low canopy crops have become commonplace in tropical agriculture (Hamidou et al., 2013).

Energy for photosynthesis is derived from solar radiation, which further determines water use in the process of transpiration and evaporation, as well as the level of crop yield. Intercrop spacing should be sufficiently wide to allow for efficient light interception (Seran & Brintha, 2010). Since it is not possible to store solar radiation for later a use, it has to be intercepted and used immediately so as to drive the process of photosynthesis.

Research findings by Jiao et al. (2008) indicate that intercropping enables maize to efficiently use strong radiation and grounds nuts to efficiently use weak light resulting in higher yields. Different intercrop canopies due to variation of planting geometry, time when planting is done, plant orientation, spatial distribution, and size of the leaves influence plant growth and productivity. Conversely, plant growth in any intercropping system depends on water availability and efficient use of other resources (Dahmardeh et al., 2010).

During competition for light there is likelihood of internode elongation of a legume. Further to that, interspecific competition can be prevented by delaying sowing time by four weeks so as to allow proper establishment of maize together with roselle crops according to (Flores-Sanchez et al., 2013).

Effect of Intercropping on Nutrients Uptake

Intercropping legumes with non-legumes may be beneficial when it comes to efficiency in absorption and use of soil nutrients. What is unclear is if the better nutrient uptake is an effect or cause from the increased yield potential. Fusuo and Li (2003) found out that when maize and peanut are intercropped, maize releases phytosiderphore which has the tendency to mobilize Fe (III) that is subsequently used by the peanut plant. This means that iron nutrition in all peanut tissues is enhanced when peanuts are intercropped with maize due to rhizosphere association between the two plants (Zuo et al., 2000; Hongchun et al., 2013).

Therefore it can be stated further that when maize and peanuts are intercropped, secretion of phytosiderophores by maize generally improve the overall iron nutrition of peanuts (Hongchun et al., 2013). Soil pH to a larger extent influence nodulation and is likely to produce a situation where there is deficiency of Mo and P despite them being essential nutrients. Reports by Hongchun et al. (2013) and Li et al. (2001) outline that intercropping augments Zn and Fe needs of peanut crops in addition to improving nitrogen uptake.

Acquisition of nitrogen by non-legume crop is comparatively better than a legume in an intercropping combination possibly due to competition. Conversely, absorption of nitrogen by soybeans is not affected significantly by intercropping. Nonetheless, Li et al. (2001) found that uptake of phosphorous by soybean is significantly enhanced through application of P in an intercropping system.

Legumes have been reported to act as catch crops that can lessen K and nitrate leaching (Askegaard & Eriksen, 2008). This makes leguminous crops not only nitrogen fixers, but also catch crops through their ability to absorb K, P, and N (Flores-Sanchez et al., 2013). As such, legumes are essential in agricultural production systems especially when K and N are constrained (Flores-Sanchez et al., 2011, 2012a). among different crops, cowpeas have demonstrated a maximum uptake of phosphorous (2Kg), nitrogen (68kg) and phosphorous (18) per hectare. Soybeans follow cowpeas at 60 kg, 2 kg, and 18 Kg of NPK respectively.

A report by Rusinamhodzi et al. (2012) outlines that micronutrient deficiencies involving molybdenum, zinc, and boron limit nitrogen fixation and legume growth. When there are high levels of nitrogen under intercropping system, legume and grain yield was low when there was a maize intercrop. Despite the cereal crop benefiting in an intercrop arrangement there is a higher possibility of faster soil nutrient depletion especially for phosphorous. This arises from increased efficiency in utilizing nutrients in soil and higher extraction through harvesting the crops (Mucheru-Muna et al., 2010). Different research findings by Chalka and Nepalia (2006) indicate that when maize is intercropped with soybean, there is lower depletion of NPK and an increased N absorption. There have been recent attempts in Africa to address soil fertility replenishment by introducing legumes to act as intercrops in addition to crop rotation programs ostensibly to reduce reliance on inorganic amendments (Sanginga & Woomer, 2009). The conflicting information on performance of legumes and cereals in intercropping systems calls for a critical examination of areas where farmers are poised to benefit from intercropping (Mpangane et al., 2004).

Effect of Legumes Intercrop and Cropping System on Soil Fertility

Challenges associated with infertility of soil do not only result from poor agronomic practices but also spread to encompass economic and social issues. The system of intercropping in a way tends to address some pertinent soil infertility concerns among poor farmers. Adeleke and

Haruna (2012) found out that pulses that are usually intercropped together with cereals are more beneficial in terms of land productivity than soil amelioration.

Research findings by Vesterager et al. (2008) indicated that intercropping maize and cowpeas is highly beneficial to nitrogen poor soils. Intercropping of maize and cowpea increases the amount of potassium, nitrogen, and phosphorus contents compared to maize in a sole cropping system (Dahmardeh et al., 2010). Infertility and degradation of soil results from application of insufficient organic matter and continuous farming of single crop. This problem is exacerbated by prolonged droughts and unreliable rainfall further resulting into poor crop production (Amos et al., 2012).

Further research findings indicate that improving and maintaining soil fertility is not achievable by applying inorganic fertilizers solely. According to Amos et al. (2012), an integrated approach where legumes, minimum soil disturbance, effective crop rotation, mulching, and cover crops are essential for managing soil fertility is the best strategy in soil fertility maintenance. Adeleke and Haruna (2012) also found that planting soybean, cowpea, lablab or groundnut increases total nitrogen in the soil. The same happened when land is left fallow. The resulting increment in total nitrogen is probably because of the legumes being efficient nitrogen fixers in the soil via symbiotic relationships.

Symbiotic nitrogen fixation in the atmosphere accounts for greater than 20 percent of the global nitrogen fixation translating into more than 45-50 million tons of fixed N for use in agriculture. In addition, allowing land to be fallow and growing of legumes have shown increased cation exchange capacity, which can be attributed to plant debris acting as mulch and later undergo decomposition to supply essential plant nutrients (Adeleke & Haruna, 2012).

Above and Below Ground Interaction in Intercropping

Jeyakumaran and Seran (2007) reported that light is a major factor with the ability to influence the final yield when crops with dissimilar morphology and maturity times are intercropped (Ijoyah, 2012). Most advantages are derived from the way intercrops interact and balance each other while exploiting resources from their environment (Oyewole, 2010). In intercropping, corn architecture has shown its influence on the amount of light radiation that is subsequently intercepted by other crops that coexist in the same intercropping system (Metwally et al., 2012).

Any reduction in light intensity that is caused by corn plants also affects photosynthetic operations of other crops in a given intercrop arrangement (Metwally et al., 2012). According to Oyewole (2010), light interception, as well as the quantity and quality of light radiation determines biomass buildup, of which determines overall crop yield. Therefore any effect on plant canopy either through shading from intercropping has proportionate impact on the yield (Dimitrios et al., 2010).

Intercropping systems with high levels of leaf cover have been associated with reduced weed population when the constituent crops are established. In their findings, Flores-Sanchez et al. (2013) have reported interaction of maize and wheat both above and below ground to be 50% and 59% respectively because of an increased nitrogen uptake. Interspecific connections of peanut/maize intercropping have also contributed to some nutritional elements essential for peanut nourishment such as increased shoot Phosphorus (P), Potassium (K), and zinc (Zn) concentrations. In addition to increase in maize and peanut productivity, legume and cereal intercropping improve growth and agronomical properties despite instances of competition for water, light, and nutrients.

Existence of various root systems reduces water loss with a subsequent increase in transpiration. This tends to create a cooler microclimate around the plant. Reports by Flores-sanchez et al. (2013) further indicate lack of significant variation of maize biomass either as a monocrop or in a maize-roselle mixture. However, intercropping reduces light interception among adjacent corn plants resulting in them becoming taller, and at the same time creating a mulching layer which not only creates a physical barrier for early germination, but also provides sufficient residual material at the soil surface (Metwally et al., 2012; Flores-Sanchez et al., 2013).

Root interactions of the facilitative type are of significant importance especially in ecosystems where there is nutrient poor soil coupled with low agricultural inputs resulting from interspecific competition for essential growth factors (Dahmardeh, 2013). When combined with peanuts, maize has shown to benefit from its extensive root system that has the capacity to absorb nutrients and water. On the other hand, peanut enables nitrogen fixation and secretes H+ in the soil, of which, this acidification promotes dissolution of phosphorous (Dahmardeh, 2013).

Previous research has examined the sensitivity of multiplicative processes of groundnut to temperature. When soil and air temperatures are increased, the number of pods, fruit set, as well as the yield of groundnut was condensed (Hamidou et al., 2013). Further, Oyewole (2010) found that pod yields of groundnut genotype declined by over 50% during flowering. At the same time, pod formation occurred at an average temperature of 40 degrees Celsius. The reason for the increased yield and growth characteristics is the phosphorous and nitrogen connections around the root zone of Bambara groundnut.

2.9. Effect of Intercropping on Growth and Yield of Legumes

Various research undertakings have taken place in regard to legume intercropping particularly in relation to annual cereal crops. The study carried out by Bhagad et al. (2006) illustrated that the practice of intercropping does not have total influence of kernel mass of groundnuts. However, the number of pods per hill, percent shelling, and weight per shell were subject to varied treatments. Another study by Hongchun et al. (2013) revealed intercropping of maize with peanut did not influence the weight of monocrop peanuts.

Further research has also highlighted that alteration of space for higher cereals to a higher degree does not affect their yield, which is important for creating a conducive environment for intercropping with legumes. For instance, using double spacing relative to single and irregular rows increased soybean yield without negatively impacting maize production (Maluleke et al., 2005). Conversely, intercropping resulted into a 58% decrease in number of soybean leaves, of which translates to a leaf area of 75% and start seed of filling of 78% (Maluleke et al., 2005). Also, Meyer (2010) in his study reports that legumes are considered as compatible components when engaging in conservation agriculture.

2.10. Intercrop Productivity

According to (Thayamini & Brintha, 2010), intercropping systems have become widespread in tropical agriculture. However, intercrops become productive when the constituent crops have largely varied growth duration since their peak nutrition requirements occur at different times. Further, interaction of differing conditions such as genetic makeup of constituent crops, agronomic conditions, and availability of resources optimize the resulting yields (Ijoyah, 2012). High productivity in an intercropped system is therefore achieved when there is least interference between the maturing crop and the crop that is growing later. Therefore, an appropriate choice of cultivars coupled with optimal manipulation of agronomic conditions and agronomic practices are the ultimate means of attaining high crop yield while making optimal use of limited resources (Thayamini & Brintha, 2010).

As per the findings by Ijoyah (2012) the highest complementary effect and crop yield occurs when the constituent crops have differing periods of growth so that they can exert their resource demands at differing periods during their growth process. Legumes have become an important component of intercropping systems partly because of their ability to fix nitrogen, which is often used to support production of the intercrops including other subsequent crops. Comparative yields have been recorded in the following intercrop systems that include: sorghum/soybean, maize/bean, wheat/mungbeans, maize/cowpea, maize/faba beans and wheat/chickpea. Out of these intercrop combinations, most of the published literature have shown that legume/non legume combination has the highest yield (Li et al., 2001).

Land Equivalent Ratio (LER)

Direct comparison of yields in an intercropped system is difficult since the different crops have different yields despite them growing on the same plot of land. The best approach is to use a common unit to measure crop productivity. In this case, land equivalent ratio (LER) is majorly used in agronomic situations when making comparative measurements of crop yields. LER can be defined as the totality of land area that is required under single culture cropping to yield the same amount of products as cropping that is done in a poly-culture system. It compares yields derived from one or more crops that have been grown as monocultures; otherwise known as pure stands. As such, intercropping capitalises on the various interactions between crops and at the same time minimising their negative interactions.

Essentially the LER quantifies the effects of both negative and beneficial interactions between the crops. LER can be obtained by dividing yield from an intercrop by yield from the same crop but from a pure stand. Then the result of this computation is added to the next crop that is also determined by dividing its yield with the one from a pure stand of the same.

The equation of calculating LER is as below;

$$\mathrm{LER_T} = \frac{\text{Yield of cowpea intercrop}}{\text{Yield of cowpea pure stand}} + \frac{\text{Yield of maize intercrop}}{\text{Yield of maize pure stand}}$$

Thus total LER,

$$\text{LERT} = \text{Partial cowpea LER (PLERc)} + \text{Partial maize LER (PLERm)}$$

$$= \frac{\mathrm{YIc}}{\mathrm{YPc}} + \frac{\mathrm{YIm}}{\mathrm{YPm}}$$

Where YIc and YIm are grain yields per ha of intercropped cowpeas and maize respectively and YPc and YPm are grain yields per ha of sole cropped cowpeas and maize respectively.

If the $\mathrm{LER_T}$ is greater than one then intercropping has a yield advantage while there is a yield disadvantage if it is less than one.In Brazil, Raposo et al. (1995) recorded high land equivalent ratio (LER) in intercropping systems that involved two by two arrangements in comparison with the situation if the intercrops were done in monocrop systems. In Ethiopia, Fininsa (1997) maize based intercropping has been reported to have high yields, whereby, its land equivalent ratio

(LER) was significantly above the one of a monocrop with a relative advantage of yield of approximately 28%.

On a similar case, altered rice bean at 30 cm and altered maize at 75 cm row proportions indicated high yield benefits relative to moisture and land use. In a 1:2 row ratio that has been set at 100% plus zero percent of fertilizer (maize 60/90 cm-rice bean 30 cm), in 2:5 at 100% plus 100% fertilizer, and finally at 2:3 at 100% fertilizer (maize 150/15-rice bean 30 cm), the land equivalent ratio (LER) was 1.84, 1.97 and 1.87 respectively.

Area Time Equivalent Ratio (ATER)

To improve on the existing characteristics of land equivalent ratio (LER), (Hiebsch & Macollam, 1980) modified the method to incorporate an entire duration that the crop stays on the piece of land from the time of planting to harvest. This updated method is called the area time equivalent ratio (ATER). Using this method in a maize plus cowpea or soybean intercropped system, the overall yield benefit ranged between 19% and 25%. Comparatively, land equivalent ratio (LER), showed an advantage that ranges from 22% to 32% over sole crops. As such, land equivalent ratio (LER) productivity estimates are approximately higher than those of area time equivalent ratio (ATER) (Allen & Obura, 1983).

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter describes where the researcher carried out the experiment. It avails details on the experimental site, the design of the experiment, treatments and their combinations; plot lay out, farm operations and method of data collection and analysis.

3.1. Site Description

The site of this experiment was located at Regina Mukiri Gichunge's farm in Kianjai Location of Tigania West sub-county. The altitude of the site is 1433 Meters above sea level in UM2 Agro Ecological Zone (AEZ). The area receives a bimodal rainfall where short rains fall between March and May while the long rains in October to December. The area receives rainfall of between 1360 mm to 1576 mm and annual mean temperatures of 18.2 – 20.6^0 C (Jaetzold et al., 2006).

3.2. Experimental Procedure and Agronomic Practices

Land preparation

Land used was cleared of bush and stumps and soil sampled for analysis. The land was then manually tilled using a hoe. It was then leveled by grading all the raised areas. Using the sisal twine and tape measure, the well prepared land was demarcated and marked with sticks. It was then subdivided into 4 blocks. A one meter path separated each block and 0.5 metre paths separated the plots that measured 4 x 3 metres.

Planting

Simultaneous planting of cowpeas and maize was done on 20th March 2015. During planting, the cowpeas were spaced at 60 cm x 20 cm. Three cowpeas seeds were sown per hill. Conversely, maize was planted at a spacing of 75 cm by 60 cm. Two maize seeds per hill were sown. Single Super Phosphate (SSP) was applied as per the design of the experiment. Cowpea received various fertilizer levels (0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg/ha) while all maize plots received a uniform 75 kg/ha No top-dressing fertilizer was applied.

Thinning

Cowpeas were thinned 14 DAS to one plant per hill. Maize plants remained two per hill.

Weeding

The crops were weeded twice on the 20th and 40th date after sowing.

Plant population/densities

Maize plant population per ha remained the same at 44,444 in both pure stand and intercropping. The Plant population for cowpeas at pure stand was 83,333 while in intercropping system it was 66,666

Table 3. 1

Crop Population Densities Per Ha

Cropping system	Cowpeas	Maize
Pure stand	83,333	44,444
Intercropping	66,666	44,444

3.3. Research Design

The Research design that was used is Randomized Complete Block Design (RCBD). The nine treatment combinations were replicated into four blocks. A total of 36 plots were established. The experiment was repeated in space in another site but in the same locality.

3.4. Materials

Cowpea M 66 was the test crop. Maize H 513 was used as the intercrop. Single Super Phosphate was (SSP) was the fertilizer used as a source of phosphorous. Other materials used were: Jembes, Tape measures, Tags, Wheelbarrow, Knapsack Sprayer, Pesticides, Planting line, Weighing Scale, Harvesting bags, Moisture meter, Labels and Marking sticks.

3.5. Treatments and Treatment Combinations

Treatments were:

Cropping systems

i. Cowpeas (M 66)

ii. Maize(H 513)

iii. Cowpeas intercropped with maize

Fertilizer levels

i. F_1 0 kg/ha

ii. F_2 25 kg/ha

iii. F_3 50 kg/ha

iv. F_4 75 kg/ha

Table 3.2

Treatment Combinations

	Fertilizer Level			
Cropping system	F_1	F_2	F_3	F_4
C	CF_1	CF_2	CF_3	CF_4
CM	$C F_1M$	$C F_2M$	$C F_3M$	CF_4M
M				M

Legend

i. C Sole cowpeas

ii. M Sole maize

iii. CM Cowpeas/maize intercrop

iv. F_1 0 kg/ha

v. F_2 25 kg/ha

vi. F_3 50 kg/ha

vii. F_4 75 kg/ha

These treatments combinations were randomized within the blocks. The plots were assigned numerical numbers for ease of tagging/field layout as shown in table 3.2

Figure 3.1

Plot Layout

3.6. Plot Layout

M	CF_1 M	CF_3 M	CF_3	CF_2 M	CF_4	CF1	CF_4 M	CF_2

CF1	CF_4 M	M	CF_2 M	CF_4	CF_1 M	CF_2	CF_3 M	CF_3

CF_4	CF_1 M	CF_1	CF_2 M	CF_4 M	CF_3	CF_3 M	CF_2	M

CF_2 M	CF_2	CF_1 M	CF_3	CF_4	M	CF_1	CF_3	CF_4 M

Plot size 4 X 3 m

3.7 Data Collection

The data collected were;

i. **Germination percentage at 7 DAS:** The total number of plants which germinated /emerged for each plot per crop was counted. A percentage of the emerged crop against the number of seeds planted was calculated as the germination rate. An average of all the plot percentages from the entire trial field was calculated and recorded as the germination percentage.

ii. **Cowpeas plant height at an interval of 14 DAS.** In every plot eight cowpeas plant were randomly selected and marked with a ribbon. Their height was taken using a meter ruler and the mean calculated.

iii. **Number of cowpeas branches from time of formation to harvesting.** Eight cowpeas plants in each plot were randomly selected and marked with a ribbon. The number of branches was counted in each plant and the mean calculated.

iv. **Number of cowpeas pods at harvesting.** Eight cowpeas plants in each plot were selected in a random manner and marked with a ribbon. Then pods per the tagged plant were counted and their mean recorded.

v. **Number of cowpeas grains per pod.** Eight pods from each of the tagged plants were selected randomly, the number of seeds was counted, and then the mean was recorded.

vi. **Yields of cowpeas at harvesting.** Harvesting was done when 95% of cowpeas pods had dried and skin colour turned brown purple. Pods were pluck off the stems and put into small gunny bags which were appropriately labeled with plot number and treatment applied. The pods were then sundried for 2 days and shelled by hand. The cowpeas grains were further dried to a moisture content of 13.5%. Their weight was measured and recorded accordingly.

vii. **Yields for maize at harvesting.** Maize was harvested when 98% of crop was dry. The cobs were harvested and put into properly labeled bags. The cobs were sundried for 2 days and shelled by hand. The grains were further sundried for 4 days to a moisture content of 13.5%, weighed and recorded.

The crop condition, growth and development were monitored on a weekly basis.

3.8. Data Analysis

The collected data in summarized in excel. Then Analysis of Variance (ANOVA) was performed using Version 22. Post hoc test was done to separate the means where the ANOVA indicated that there were significant differences ($P \leq 0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents research findings in tables and figures. It shows how analysis of variance was done and provides information on post- hoc analysis where necessary.

4.1. Germination Rate

The germination rate of crops was observed on the 7th day after sowing. The number of germinated and emerged plants for cowpeas and maize per hole within a plot was counted. The germination percentage of each crop is as shown in Table 4.1.

Table 4.1

Germination of Crops at 7th Day after Sowing

Crop	**% germination**
Cowpeas	100
Maize	95

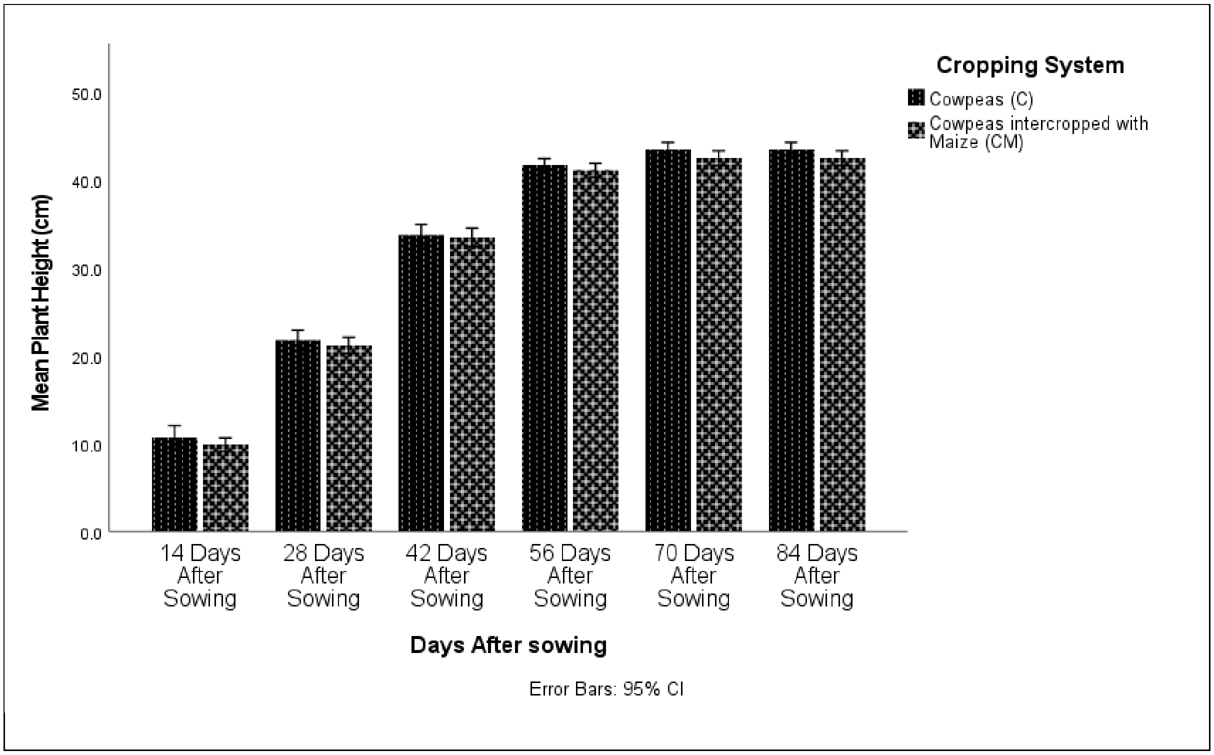
The crops had germinated well. Cowpeas recorded 100% germination and showed strong growth vigour. Maize had a lower germination percentage perhaps due to seed effects. Overall germination rate was good for experimental purposes and could give valid data.

4.2. Plant Height

Heights of eight randomly selected cowpea plants per plot were measured at two weeks interval from the date of sowing. The measurement was done using a metre ruler from the ground level. The results obtained are shown in Figure 4.1.

Figure 4.1

The Effect of Cropping System on Plant Height

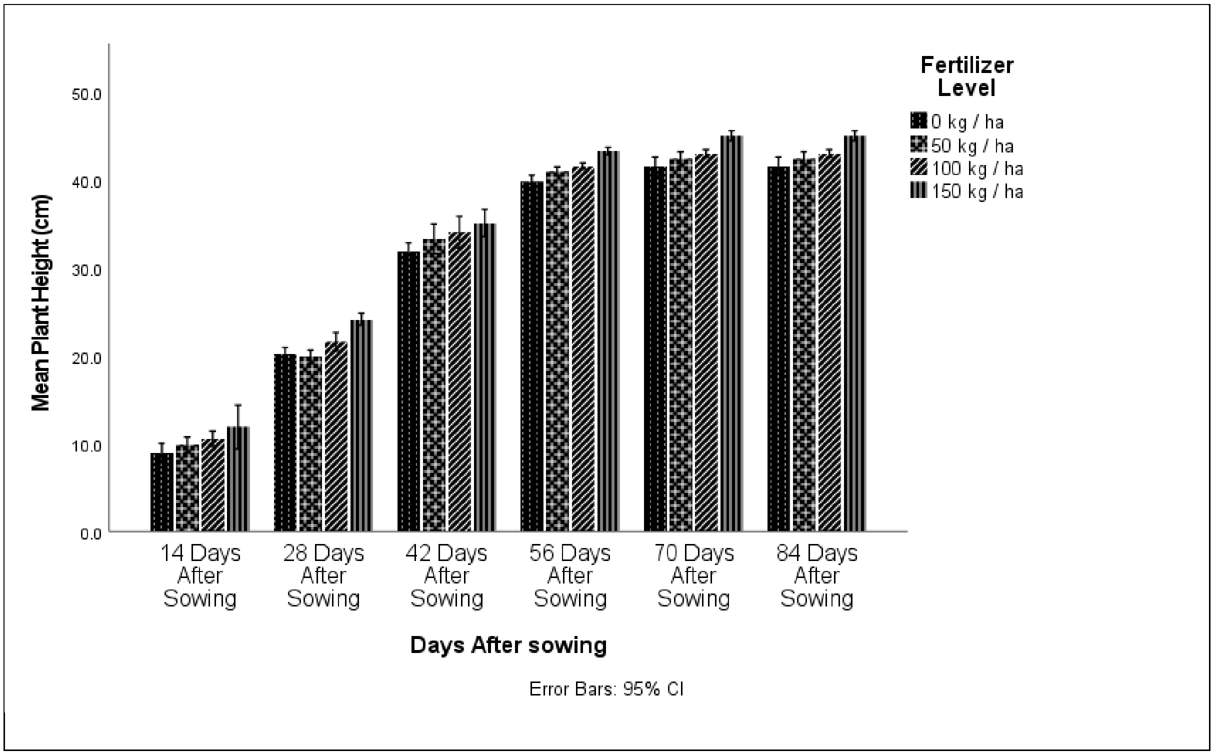


It can be observed from Figure 4.1 that sole cowpeas showed a slightly higher growth compared with cowpeas intercropped with maize.

From the ANOVA, refer to appendix I plant heights were significantly affected by cropping system ($p<0.05$). Plant heights were not significantly affected by the interaction between cropping system and fertilizer level ($p>0.05$) at harvesting stage. This is an indication that the sole cowpea utilized the phosphorus fertilizer applied judiciously in growth and development processes without much competition from maize.

Figure 4.2

The Effect of Fertilizer Level on Plant Height



It can be observed from Figure 4.2 that application of 75 kg/ha recorded the most height followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively.

ANOVA results refer to appendix I indicated that plant heights were significantly affected by fertilizer levels ($p<0.05$) at harvesting stage.

The reason for these observations may be due to the fact that phosphorous is required in significant amounts in root and shoot tips because these are regions where cell division is rapid and metabolism is high (Ndakidemi & Dakora, 2007).

It has therefore been demonstrated that low levels of P in the soil limits nitrogen fixation and productivity of cowpea. This is because P plays an important role in nitrogen fixation, nodulation, root hair formation, and general root development.

The post hoc test for fertilizer level showed that there were significant differences between 0 kg/ha and the rest of the fertilizer levels (25 kg/ha, 50 kg/ha and 75 kg /ha) on plant height. However there were no significant differences between 25 kg/ha and 50 kg/ha but significant differences are observed between 25 kg/ha and 75 kg /ha. 75 kg /ha recorded significant differences with the rest of fertilizer levels as shown in Table 4.2.

Table 4.2

LSD comparisons on Fertilization Levels on Plant Height

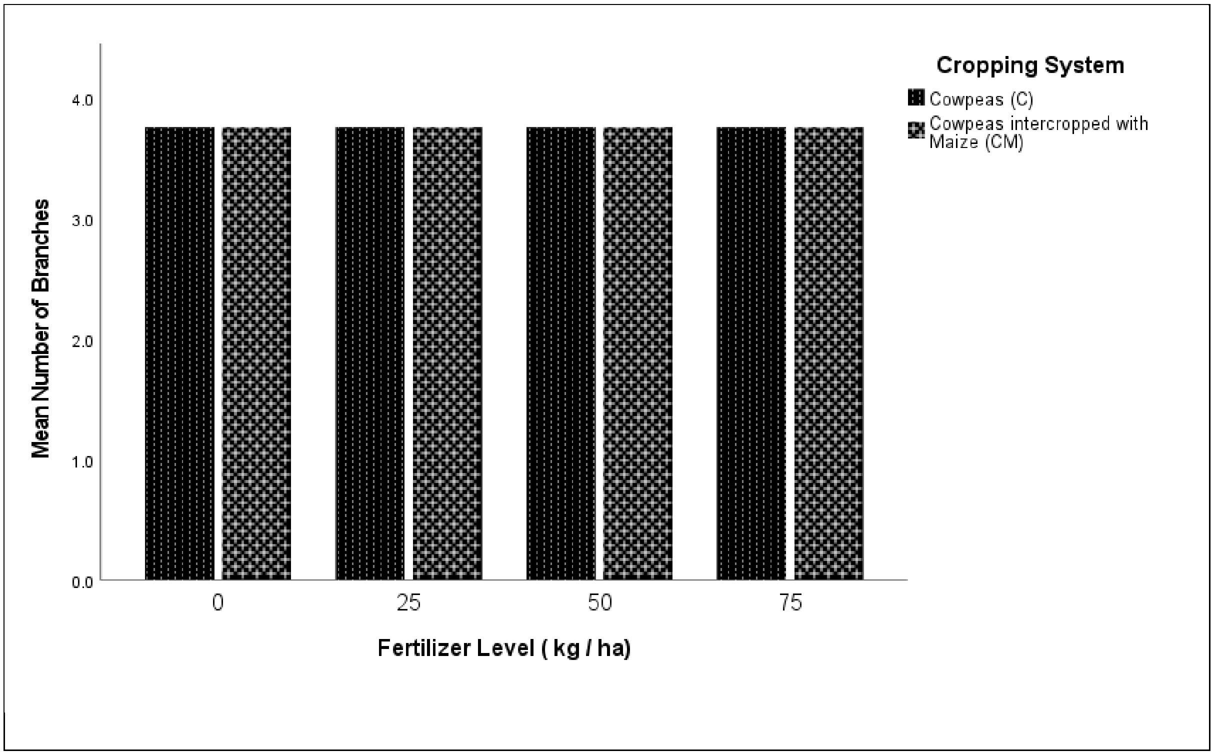
Kg / ha	**0**	**25**	**50**	**75**
0		-0.863*	-1.437*	-3.475*
25	0.863*		-0.575	-2.612*
50	1.438*	0.575		-2.038*
75	3.475*	2.612*	2.038*	

Number of Branches

Recording the number of cowpea branches was done by randomly selecting eight cowpea plants per plot and counting the number of branches per plant in every plot every 2 weeks until maturity. The first measurement was done fourteen Days after Sowing (DAS). The mode number branches were recorded and analysis is as shown in Figure 4.3.

Figure 4.3

The effect of cropping system and fertilizer level on number of branches



The number of branches increased irrespective of the cropping system until a maximum of 4 branches was reached after which it remained constant until the plants dried as seen in Figure 4.3.

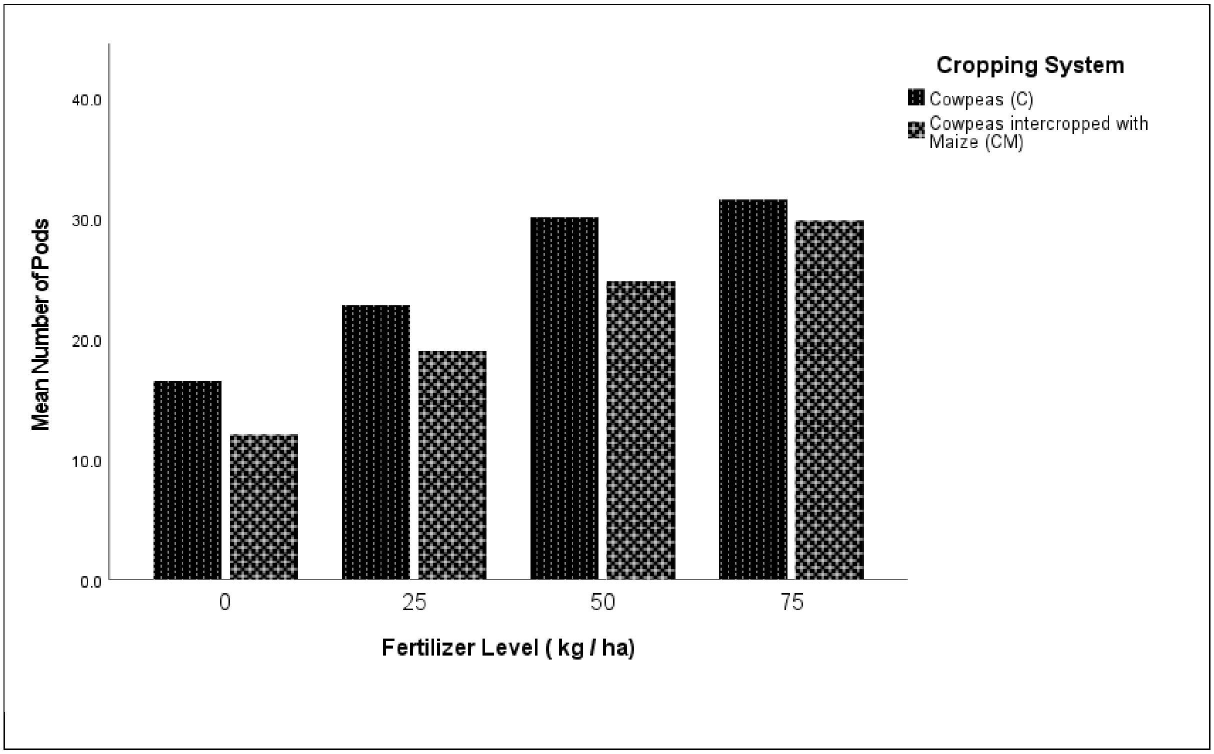
From the ANOVA, refer to appendix II, number of branches were not significantly affected by fertilizer levels and cropping pattern ($p>0.05$). Similarly the number of branches were not significantly affected by the interaction between fertilizer levels and cropping system ($p>0.05$). This result does not agree with Krasilnikoff et al. (2003) who recorded a significant increase in number of branches with increase in phosphorous level. This difference can perhaps be attributed to the genetic constitution of the variety M 66.

4.3. Number of Pods

All cowpea pods from the sampled plants were counted at harvesting and the mode was recorded for analysis. The results are as shown in Figure 4.4.

Figure 4.4

The effect of cropping system and fertilizer levels on the number of pods of cowpeas



There was a proportionate increase in the count of pods with an increase in fertilizer level irrespective of the cropping system. 75 kg/ha produced the highest number of pods in either cropping system followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively. However sole cowpeas produced more pods compared to cowpeas intercropped with maize as shown in Figure 4.4.

From the ANOVA, refer to appendix III, the number of pods were significantly affected by cropping system ($p<0.05$). Similarly the number of pods were significantly affected by fertilizer levels ($p<0.05$). This result agrees with Ndakidemi and Dakora (2007) whose findings recorded a reduction in cowpea number of pods per plant under intercropping system compared to sole cropping. However, the number of pods were not significantly affected by the interaction between fertilizer levels and cropping system ($p>0.05$). Since cropping system and fertilizer levels recorded a significant difference ($p<0.05$) a post hoc test was done.

The post hoc test results showed that there were significant differences between 0 kg/ha, 25 kg/ha, 50 kg/ha and 75 kg/ha. 75 kg/ha was superior followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively as shown in Table 4.3. However, the post hoc test did not indicate any significant difference between 50 kg/ha and 75 kg/ha. Phosphorous had a significant effect on number of pods per plant. These results agree with the findings of Nkaa et al. (2014) which showed that increased P fertilizer application increased number of pods per plant. This is probably because Phosphorus stimulates root and plant growth development in crop production and cowpea is not an exception.

Table 4.3

LSD comparisons on Fertilization Levels on Number of Pods

Kg / ha	**0**	**25**	**50**	**75**
0		-6.625*	-13.125*	-16.375*
25	6.625*		-6.500*	-9.750*
50	13.125*	6.500*		-3.250
75	16.375*	9.750*	3.250	

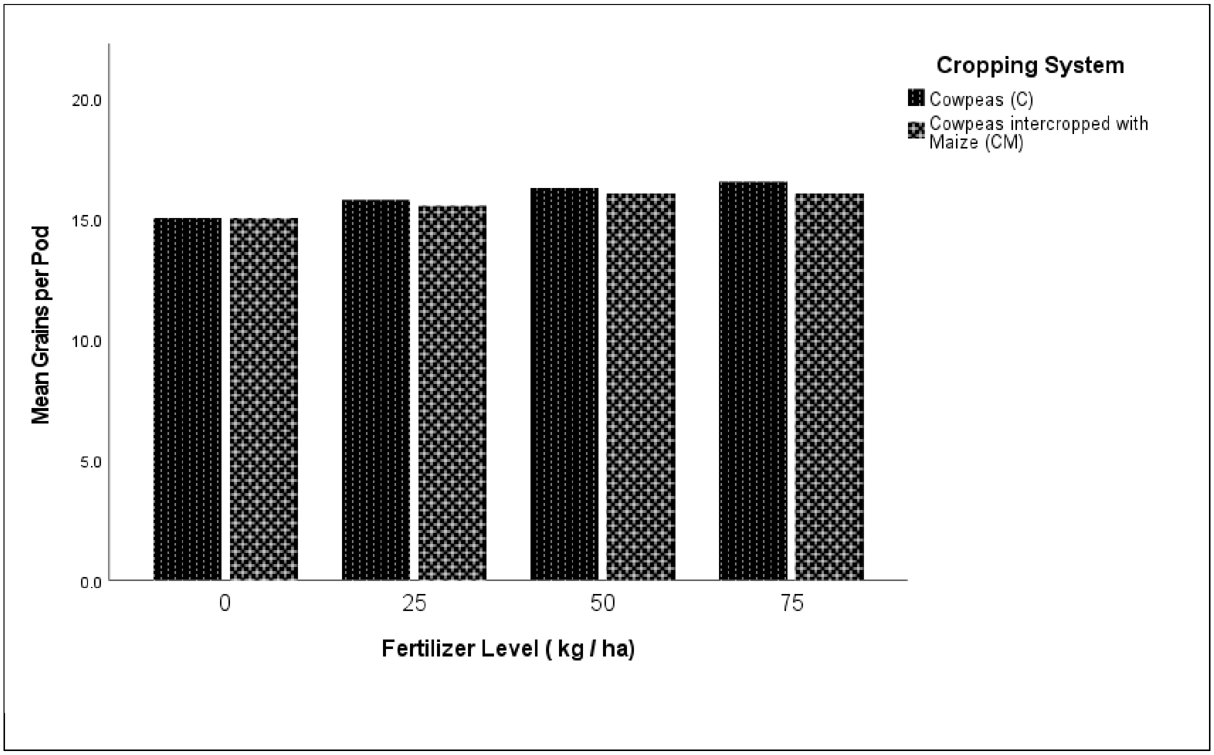
*The mean difference is significant at 0.05 level

4.4.Grains per Pod

The number of cowpea grains from eight randomly selected dry pods from eight plants in each plot was counted and weight recorded. The results are shown in Figure 4.5.

Figure 4.5

The effect of fertilizer levels on the number grains per pod of sole and intercropped cowpeas



The research found out that application of 75 kg/ha and 50 kg/ha produced slightly higher number of grains per pod in sole cowpeas followed by 25 kg/ha whereas 0 kg/ha produced the least. The study further revealed that in cowpeas intercropped with maize, 75 kg/ha and 50 kg/ha produced more seeds per pod followed 25 kg/ha and 0 kg/ha respectively as shown in Figure 4.5.

From the ANOVA, refer to appendix IV, the number of grains per pod were not significantly affected by interaction between cropping system fertilizer level ($p>0.05$). Similarly the numbers of grains per pod were not significantly affected by cropping system ($p>0.05$). However, the number of grains per pod were significantly affected by fertilizer levels ($p<0.05$). Post-hoc test was conducted as shown in Table 4.4 which showed that 75 kg/ha, 50 kg/ha and 25 kg/ha significantly produced more grains per pod compared to 0 kg/ha. Similarly 75 kg/ha and 50 kg/ha gave more grains per pod compared to 25 kg/ha. However, 75 kg/ha showed no significant effect in comparison with 50 kg /ha. The findings contradict with those of Singh et al. (2011) who reported no significant effect of P on number of seeds per pod.

Table 4.4

LSD comparisons on Fertilization Levels on Grains per Pod

Kg / ha	**0**	**25**	**50**	**75**
0		-0.625*	-1.125*	-1.250*
25	0.625*		-0.500*	-0.625*
50	1.125*	0.500*		0.125
75	1.250*	0.625*	0.125	

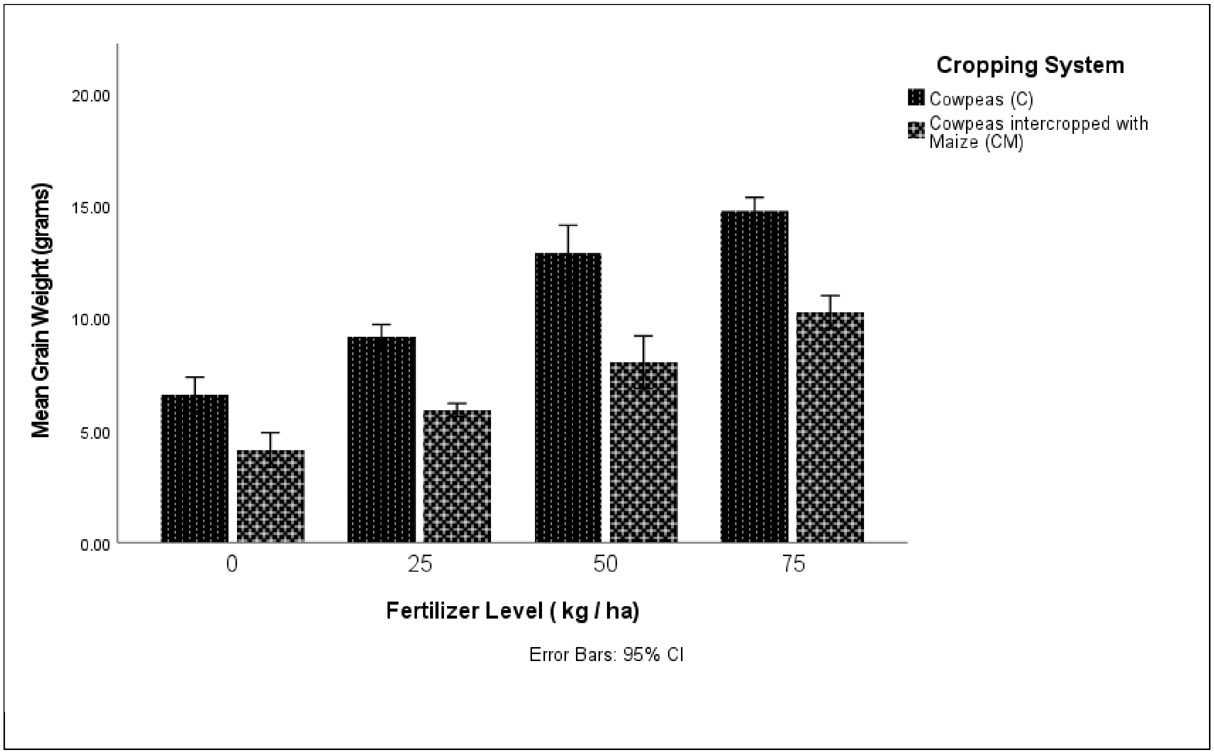
*The mean difference is significant at 0.05 level

4.5. One Hundred (100) Cowpeas Grain Weight

The weight of 100 randomly selected cowpea grains from each plot was measured and mean recorded. The results are shown in Figure 4.6.

Figure 4.6

The effect of fertilizer levels on 100 grain weight of sole and intercropped cowpeas



It can be observed from figure 4.6 that sole cowpea recorded higher grain weight compared intercropped cowpea. Further the mean gain weight increased with increase in fertilizer level.

The ANOVA results refer to appendix V indicated that the mean grain weight was significantly affected by cropping system ($p<0.05$). The results further showed that the mean grain weight was significantly affected by fertilizer level ($p<0.05$). The mean grain weight was likewise significantly affected by the interaction between cropping system and fertilizer ($p<0.05$).

Post-hoc test indicated that the various fertilizer levels had significant effect on 100 grain weight whereby 75 kg/ha and 50 kg/ha performed better than 25 kg/ha and 0 kg/ha as shown in Table4.5. This finding agrees with those of Nkaa et al. (2014) who found out that the weight of 50 seeds was enhanced by application of phosphorous fertilizer. The mean difference between 75 kg/ha and 50 kg/ha was not significant.

Table 4.5

LSD comparisons on Fertilization Levels on 100 Grain Weight

Kg / ha	**0**	**25**	**50**	**75**
0	■	-2.18*	-5.0925*	-7.1425*
25	2.18*	■	-2.9125*	-4.9625*
50	5.0925*	2.9125*	■	-2.0500
75	7.1425*	4.9625*	2.0500	■

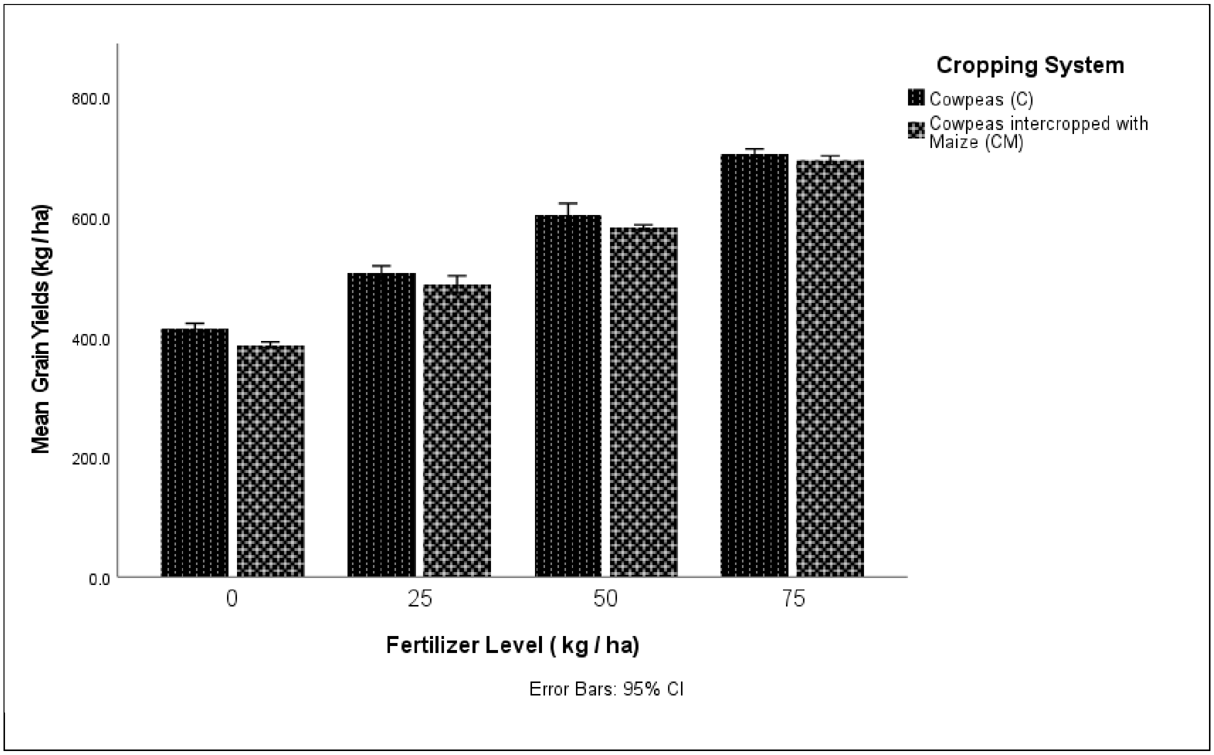
*The mean difference is significant at 0.05 level

4.6. Cowpeas Grain Yield

Cowpea pods harvested from each plot were threshed and the grains dried to a moisture content of 13% before weighing. The dried grains were then weighed and the weight was recorded for every plot. The records were then converted to kg/ha for ease of comparison. This is shown in Figure 4.7.

Figure 4.7.

The effect of fertilizer levels on cowpeas grain yields of sole and intercropped cowpeas



The research established that cowpea grain yields were more when 75 kg/ha was applied followed by 50 kg/ha, 25 kg/ha whereas 0 kg/ha. Similarly in an intercropping system 75 kg/ha produced more yields followed by 50 kg/ha, 25 kg/ha whereas 0 kg/ha gave the least yield.

From the ANOVA, refer to appendix VI, grain yields were significantly affected by cropping system ($p<0.05$). The grain yields were similarly affected by fertilizer level ($p<0.05$).The ANOVA results further showed that grain yields were significantly affected by the interaction between fertilizer levels and cropping system ($p<0.05$). Since fertilizer levels showed significant difference ($p<0.05$) post hoc test was done.

The post hoc test results showed no significant difference between 0 kg/ha, 25 kg/h 50 kg/ha and 75 kg/ha as shown in Table 4.6. This corresponds to findings from other researchers including Haruna and Usman (2013) who also reported significant increase in yield of cowpea in response to phosphorus application. This is because P is required in large amounts by leguminous plants not only for growth but also in promoting leaf area, biomass, grain yield, number and mass of nodules (Wakeel et al., 2011).

Table 4. 6

LSD comparisons on Fertilization Levels on Grain Yields

Kg / ha	**0**	**25**	**50**	**75**
0		-96.875*	-193.000*	-299.875*
25	96.875*		-96.125*	-203.000*
50	193.000*	96.125*		-106.875*
75	299.875*	203.000*	106.875*	

*The mean difference is significant at 0.05 level

4.7. Land Equivalent Ratios (LER) For Cowpeas and Maize under Different Cropping Systems.

The Land equivalent ratio (LER) was calculated for each instance and used to compare yields of cowpeas and maize under different cropping systems. The formula used in calculating LER is

$$\text{LER}_\text{T} = \frac{Yield\ of\ cowpea\ intercrop}{Yield\ of\ cowpea\ pure\ stand} + \frac{Yield\ of\ maize\ intercrop}{Yield\ of\ maize\ pure\ stand}$$

Thus total LER,

LERT = Partial cowpea LER (PLERc) + Partial maize LER (PLERm)

LER (T) = PLERc + PLERm

$$= \frac{YIc}{YPc} + \frac{YIm}{YPm}$$

Where YIc and YIm are grain yields per ha of intercropped cowpeas and maize respectively and YPc and YPm are grain yields per ha of sole cropped cowpeas and maize, respectively

Table 4.7

Partial and Total Land Equivalent Ratios for Cowpeas and Maize

Cropping system	**Fertilizer level (kg/ha)**	**Crop**	**Mean yields(kg/ha)**	**Partial LER Cowpeas**	**Partial LER Maize**	**Total LER**
Pure stand		Maize	1739.25			1
	0	Cowpeas	413.5			1
	25		506.25			1
	50		604			1
	75		705.75			1
Cowpeas +Maize intercrop		Maize	1525.05		0.8768	1.8115
	0	Cowpeas	386.5	0.9347		
		Maize	1408.05		0.8096	1.7726
	25	Cowpeas	487.5	0.9630		
		Maize	1391		0.7998	1.7634
	50	Cowpeas	582	0.9636		
		Maize	1647.33		0.9471	1.9305
	75	Cowpeas	694	0.9834		

Cowpea has a higher Partial LER compared to maize. The partial LER for cowpeas ranged from 0.9347-0.9834 whereas the Partial LER for maize ranged from 0.7998-0.9471. Intercropping cowpeas and maize at 75 kg/ha SSP gave the highest partial LER for both cowpeas and maize as shown in Table 4.7. Total LER for both cowpeas and maize is >1. The highest total LER is 1.9305 whereby cowpeas were intercropped with maize using 75 kg/ha SSP.

The higher LER in cowpeas than maize is probably due to the dominant effect cowpea in an intercropping system as a result of the ability of cowpea to grow fast and make use of the available nutrients before maize establishes a comprehensive root system.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The research was conducted with a primary purpose of determining the effects of intercropping maize with cowpeas and phosphorous on performance of cowpeas. Majority of farmers don't apply fertilizer on cowpeas. Further due to small land holdings farmers practice intercropping. The experiment was two factorial (cropping system and fertilizer levels) in a completely randomized block design. There were four blocks and 36 treatments. The research collected data on plant height, number of branches, number of pods, grains per pod, grain weight and grain yield. In an intercropping system it was necessary also to calculate the land equivalent ratio which is critical in determining land productivity. Collected data was summarized and analysed using SPSS version 22.

5.2 Conclusions

The crops which were used in the research experiment had a good germination rate (over 95%) that gave a good crop stand for evaluation of cropping systems and phosphorous level on growth and yields of cowpeas. Any reduced germination was due to seed and not climatic conditions.

Plant heights were significantly affected by cropping system. Similarly plant heights were significantly affected by fertilizer levels at harvesting stage. Fertilizer level 75 kg/ha showed a higher plant height followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively

There was no notable difference in the number of branches under different cropping systems and different fertilizer level.

The number of pods was more in sole cowpeas cropping system as compared to cowpeas intercropped with maize. The number of pods increased with increase in fertilizer level irrespective of the cropping system. 75 kg/ha produced the highest number of pods in either cropping system followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively. Since there was no difference between 75 kg/ha and 50 kg/ha on the number of pods growers interested only on the number of pods can adopt 50 kg/ha because it will be economical. Phosphorous is important for pod development, photosynthesis, and grain filling in leguminous crops. It is also responsible for nodulation in cowpea. Thus increased nodulation resulted in higher nitrogen fixation and ultimately the number of pods per plant.

The number of grains per pod was not significantly affected by cropping system. However the number of grains per pod was significantly affected by fertilizer level with an exception of 75 kg/ha and 50 kg/ha where no significant difference was recorded.

The cowpeas grain weight was more in sole cowpeas cropping system as compared to intercropping. 75 kg/ha had more grain weight followed by 50 kg/ha, 25 kg/ha and 0 kg/ha respectively. The difference was significant.

Cowpeas grain yields were more in sole cowpeas cropping system as compared cowpeas intercropped with maize. 75 kg/ha of phosphorous gave more yields followed by 50 kg/ha, 25 kg/ha and 0 kg/ha.

Total LER for both cowpeas and maize is >1 and therefore intercropping was beneficial.

5.3 Recommendations

From this study the following recommendations can be made;

I. Intercropping cowpeas and maize using Single Super Phosphate (SSP) at a rate of 75 kg/ha can be adopted for cowpeas and maize intercropping systems for increased yields in phosphorous deficient soils.

II. More work to be done to determine effects of intercropping cowpeas with other cereal crops other than maize.

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APPENDICES

Appendix I: The Effects of Different Levels of Fertilizer on Cowpeas Height under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Plant Height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	.301	3	.100	.171	.915
CS	8.611	1	8.611	14.686	.001
FL	52.386	3	17.462	29.780	.000
CS * FL	1.046	3	.349	.595	.625
Error	12.314	21	.586		
Total	74.659	31			

a. R Squared = .835 (Adjusted R Squared = .757)

Appendix II: The Effects of Different Levels of Fertilizer on Number of Cowpeas Branches under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Number of Branches					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	.000	3	.000	.000	1.000
CS	.000	1	.000	.000	1.000
FL	.000	3	.000	.000	1.000
CS * FL	.000	3	.000	.000	1.000
Error	24.000	117	.205		
Total	24.000	127			

a. R Squared = .000 (Adjusted R Squared = -.085)

Appendix III: The Effects of Different Levels of Fertilizer on Number of Cowpeas Pods under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Number of Pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	63.844	3	21.281	2.397	.097
CS	116.281	1	116.281	13.100	.002
FL	1264.344	3	421.448	47.479	.000
CS * FL	13.594	3	4.531	.510	.679
Error	186.406	21	8.876		
Total	1644.469	31			

a. R Squared = .887 (Adjusted R Squared = .833)

Appendix IV: The Effects of Different Levels of Fertilizer on Number of Cowpeas Grains per Pod under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Grains per Pod

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BK	.750	3	.250	1.909	.159
CS	.500	1	.500	3.818	.064
FL	7.750	3	2.583	19.727	.000
CS * FL	.250	3	.083	.636	.600
Error	2.750	21	.131		
Total	12.000	31			

a. R Squared = .771 (Adjusted R Squared = .662)

Appendix V: The Effects of Different Levels of Fertilizer on Cowpeas Grain Weight under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Grain Weight (grams)					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BK	.441	3	.147	.518	.674
CS	114.156	1	114.156	402.731	.000
FL	238.026	3	79.342	279.910	.000
CS * FL	7.191	3	2.397	8.456	.001
Error	5.953	21	.283		
Total	365.766	31			

a. R Squared = .984 (Adjusted R Squared = .976)

Appendix VI: The Effects of Different Levels of Fertilizer on Cowpeas Grain Yields under Different Cropping Systems

Tests of Between-Subjects Effects

Dependent Variable: Grain Yields (kg / ha)					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BK	112.375	3	37.458	.824	.495
CS	3160.125	1	3160.125	69.553	.000
FL	396860.125	3	132286.708	2911.590	.000
CS * FL	245.125	3	81.708	1.798	.178
Error	954.125	21	45.435		
Total	401331.875	31			

a. R Squared = .998 (Adjusted R Squared = .996)

Appendix VII: Experimental Data

BK	FL	CS	DAS	PH	NB	NP	GPP	GW	CY
1.0	.0	.0	14.0	9.6					
1.0	.0	1.0	14.0	6.0					
1.0	25.0	.0	14.0	11.6					
1.0	25.0	1.0	14.0	11.0					
1.0	50.0	.0	14.0	12.3					
1.0	50.0	1.0	14.0	11.8					
1.0	75.0	.0	14.0	19.0					
1.0	75.0	1.0	14.0	12.1					
2.0	.0	.0	14.0	8.3					
2.0	.0	1.0	14.0	10.3					
2.0	25.0	.0	14.0	10.6					
2.0	25.0	1.0	14.0	9.4					
2.0	50.0	.0	14.0	10.9					
2.0	50.0	1.0	14.0	10.5					
2.0	75.0	.0	14.0	11.8					
2.0	75.0	1.0	14.0	11.0					
3.0	.0	.0	14.0	8.9					
3.0	.0	1.0	14.0	8.8					
3.0	25.0	.0	14.0	9.3					
3.0	25.0	1.0	14.0	9.2					
3.0	50.0	.0	14.0	9.9					
3.0	50.0	1.0	14.0	9.6					
3.0	75.0	.0	14.0	11.0					
3.0	75.0	1.0	14.0	10.2					
4.0	.0	.0	14.0	9.5					
4.0	.0	1.0	14.0	9.9					
4.0	25.0	.0	14.0	8.9					
4.0	25.0	1.0	14.0	8.9					
4.0	50.0	.0	14.0	9.8					
4.0	50.0	1.0	14.0	9.7					
4.0	75.0	.0	14.0	10.2					
4.0	75.0	1.0	14.0	9.9					
1.0	.0	.0	28.0	22.2					
1.0	.0	1.0	28.0	20.3					
1.0	25.0	.0	28.0	18.4					
1.0	25.0	1.0	28.0	19.2					
1.0	50.0	.0	28.0	24.2					
1.0	50.0	1.0	28.0	21.3					
1.0	75.0	.0	28.0	25.5					
1.0	75.0	1.0	28.0	24.0					
2.0	.0	.0	28.0	20.1					
2.0	.0	1.0	28.0	20.0					

2.0	25.0	.0	28.0	21.0					
2.0	25.0	1.0	28.0	19.3					
2.0	50.0	.0	28.0	20.2					
2.0	50.0	1.0	28.0	20.9					
2.0	75.0	.0	28.0	23.8					
2.0	75.0	1.0	28.0	22.7					
3.0	.0	.0	28.0	19.4					
3.0	.0	1.0	28.0	20.1					
3.0	25.0	.0	28.0	20.6					
3.0	25.0	1.0	28.0	20.2					
3.0	50.0	.0	28.0	22.3					
3.0	50.0	1.0	28.0	22.0					
3.0	75.0	.0	28.0	24.8					
3.0	75.0	1.0	28.0	24.3					
4.0	.0	.0	28.0	20.1					
4.0	.0	1.0	28.0	19.6					
4.0	25.0	.0	28.0	20.3					
4.0	25.0	1.0	28.0	20.3					
4.0	50.0	.0	28.0	21.0					
4.0	50.0	1.0	28.0	20.8					
4.0	75.0	.0	28.0	24.0					
4.0	75.0	1.0	28.0	24.1					
1.0	.0	.0	42.0	33.2	3.0				
1.0	.0	1.0	42.0	31.8	3.0				
1.0	25.0	.0	42.0	36.7	3.0				
1.0	25.0	1.0	42.0	35.6	3.0				
1.0	50.0	.0	42.0	37.7	3.0				
1.0	50.0	1.0	42.0	37.1	3.0				
1.0	75.0	.0	42.0	38.3	3.0				
1.0	75.0	1.0	42.0	37.3	3.0				
2.0	.0	.0	42.0	30.3	3.0				
2.0	.0	1.0	42.0	30.0	3.0				
2.0	25.0	.0	42.0	30.6	3.0				
2.0	25.0	1.0	42.0	31.3	3.0				
2.0	50.0	.0	42.0	32.1	3.0				
2.0	50.0	1.0	42.0	32.0	3.0				
2.0	75.0	.0	42.0	33.0	3.0				
2.0	75.0	1.0	42.0	33.0	3.0				
3.0	.0	.0	42.0	32.0	3.0				
3.0	.0	1.0	42.0	33.2	3.0				
3.0	25.0	.0	42.0	32.4	3.0				
3.0	25.0	1.0	42.0	33.2	3.0				
3.0	50.0	.0	42.0	33.6	3.0				
3.0	50.0	1.0	42.0	33.3	3.0				
3.0	75.0	.0	42.0	35.0	3.0				

3.0	75.0	1.0	42.0	34.6	3.0				
4.0	.0	.0	42.0	32.3	3.0				
4.0	.0	1.0	42.0	32.1	3.0				
4.0	25.0	.0	42.0	33.4	3.0				
4.0	25.0	1.0	42.0	33.2	3.0				
4.0	50.0	.0	42.0	33.7	3.0				
4.0	50.0	1.0	42.0	33.0	3.0				
4.0	75.0	.0	42.0	35.0	3.0				
4.0	75.0	1.0	42.0	34.6	3.0				
1.0	.0	.0	56.0	40.1	4.0				
1.0	.0	1.0	56.0	38.0	4.0				
1.0	25.0	.0	56.0	42.0	4.0				
1.0	25.0	1.0	56.0	40.0	4.0				
1.0	50.0	.0	56.0	42.0	4.0				
1.0	50.0	1.0	56.0	41.6	4.0				
1.0	75.0	.0	56.0	44.0	4.0				
1.0	75.0	1.0	56.0	43.6	4.0				
2.0	.0	.0	56.0	41.0	4.0				
2.0	.0	1.0	56.0	40.1	4.0				
2.0	25.0	.0	56.0	41.0	4.0				
2.0	25.0	1.0	56.0	40.6	4.0				
2.0	50.0	.0	56.0	41.3	4.0				
2.0	50.0	1.0	56.0	41.0	4.0				
2.0	75.0	.0	56.0	43.0	4.0				
2.0	75.0	1.0	56.0	42.7	4.0				
3.0	.0	.0	56.0	40.0	4.0				
3.0	.0	1.0	56.0	40.0	4.0				
3.0	25.0	.0	56.0	41.2	4.0				
3.0	25.0	1.0	56.0	41.0	4.0				
3.0	50.0	.0	56.0	42.0	4.0				
3.0	50.0	1.0	56.0	41.0	4.0				
3.0	75.0	.0	56.0	43.0	4.0				
3.0	75.0	1.0	56.0	43.0	4.0				
4.0	.0	.0	56.0	40.0	4.0				
4.0	.0	1.0	56.0	39.6	4.0				
4.0	25.0	.0	56.0	41.2	4.0				
4.0	25.0	1.0	56.0	41.0	4.0				
4.0	50.0	.0	56.0	42.0	4.0				
4.0	50.0	1.0	56.0	41.8	4.0				
4.0	75.0	.0	56.0	44.0	4.0				
4.0	75.0	1.0	56.0	43.1	4.0				
1.0	.0	.0	70.0	42.0	4.0				
1.0	.0	1.0	70.0	40.0	4.0				
1.0	25.0	.0	70.0	44.0	4.0				
1.0	25.0	1.0	70.0	41.2	4.0				

1.0	50.0	.0	70.0	43.8	4.0				
1.0	50.0	1.0	70.0	43.1	4.0				
1.0	75.0	.0	70.0	46.0	4.0				
1.0	75.0	1.0	70.0	44.8	4.0				
2.0	.0	.0	70.0	43.0	4.0				
2.0	.0	1.0	70.0	41.0	4.0				
2.0	25.0	.0	70.0	43.6	4.0				
2.0	25.0	1.0	70.0	42.6	4.0				
2.0	50.0	.0	70.0	43.1	4.0				
2.0	50.0	1.0	70.0	42.0	4.0				
2.0	75.0	.0	70.0	44.9	4.0				
2.0	75.0	1.0	70.0	44.2	4.0				
3.0	.0	.0	70.0	43.3	4.0				
3.0	.0	1.0	70.0	42.0	4.0				
3.0	25.0	.0	70.0	42.1	4.0				
3.0	25.0	1.0	70.0	41.9	4.0				
3.0	50.0	.0	70.0	43.0	4.0				
3.0	50.0	1.0	70.0	42.6	4.0				
3.0	75.0	.0	70.0	45.0	4.0				
3.0	75.0	1.0	70.0	44.2	4.0				
4.0	.0	.0	70.0	41.2	4.0				
4.0	.0	1.0	70.0	40.0	4.0				
4.0	25.0	.0	70.0	42.0	4.0				
4.0	25.0	1.0	70.0	42.0	4.0				
4.0	50.0	.0	70.0	43.4	4.0				
4.0	50.0	1.0	70.0	43.0	4.0				
4.0	75.0	.0	70.0	46.0	4.0				
4.0	75.0	1.0	70.0	45.2	4.0				
1.0	.0	.0	84.0	42.0	4.0	16.0	15.0	6.90	420.0
1.0	.0	1.0	84.0	40.0	4.0	12.0	15.0	4.56	390.0
1.0	25.0	.0	84.0	44.0	4.0	21.0	16.0	9.50	500.0
1.0	25.0	1.0	84.0	41.2	4.0	18.0	16.0	6.00	480.0
1.0	50.0	.0	84.0	43.8	4.0	30.0	16.0	12.00	590.0
1.0	50.0	1.0	84.0	43.1	4.0	25.0	16.0	7.10	586.0
1.0	75.0	.0	84.0	46.0	4.0	34.0	17.0	14.20	700.0
1.0	75.0	1.0	84.0	44.8	4.0	29.0	16.0	10.10	690.0
2.0	.0	.0	84.0	43.0	4.0	18.0	15.0	6.70	410.0
2.0	.0	1.0	84.0	41.0	4.0	14.0	15.0	3.80	388.0
2.0	25.0	.0	84.0	43.6	4.0	24.0	16.0	8.80	515.0
2.0	25.0	1.0	84.0	42.6	4.0	20.0	16.0	5.70	500.0
2.0	50.0	.0	84.0	43.1	4.0	31.0	16.0	12.90	600.0
2.0	50.0	1.0	84.0	42.0	4.0	28.0	16.0	8.90	580.0
2.0	75.0	.0	84.0	44.9	4.0	37.0	16.0	15.10	705.0
2.0	75.0	1.0	84.0	44.2	4.0	33.0	16.0	10.90	690.0
3.0	.0	.0	84.0	43.3	4.0	18.0	15.0	5.90	416.0

3.0	.0	1.0	84.0	42.0	4.0	12.0	15.0	3.60	384.0
3.0	25.0	.0	84.0	42.1	4.0	26.0	15.0	9.40	510.0
3.0	25.0	1.0	84.0	41.9	4.0	20.0	15.0	5.80	488.0
3.0	50.0	.0	84.0	43.0	4.0	30.0	16.0	13.90	610.0
3.0	50.0	1.0	84.0	42.6	4.0	20.0	16.0	8.00	580.0
3.0	75.0	.0	84.0	45.0	4.0	21.0	16.0	14.90	710.0
3.0	75.0	1.0	84.0	44.2	4.0	29.0	16.0	9.80	698.0
4.0	.0	.0	84.0	41.2	4.0	14.0	15.0	6.90	408.0
4.0	.0	1.0	84.0	40.0	4.0	10.0	15.0	4.50	384.0
4.0	25.0	.0	84.0	42.0	4.0	20.0	16.0	9.00	500.0
4.0	25.0	1.0	84.0	42.0	4.0	18.0	15.0	6.10	482.0
4.0	50.0	.0	84.0	43.4	4.0	29.0	17.0	12.70	616.0
4.0	50.0	1.0	84.0	43.0	4.0	26.0	16.0	8.10	582.0
4.0	75.0	.0	84.0	46.0	4.0	34.0	17.0	14.80	708.0
4.0	75.0	1.0	84.0	45.2	4.0	28.0	16.0	10.20	698.0

Appendix VIII: Soil Analysis Results from Agriq Quest Nairobi.

Soil property	**Parts Per Million(ppm)**
PH	6.47
EC	0.05
Potassium	0.73
Sodium	23
Calcium	2.50
Magnesium	1.24
Nitrates	0.31
Sulphates	27.6
Phosphates	2.12
Iron	0.26
Manganese	0.45
Zinc	0.21
Copper	0.01

Appendix IX: Climate Data for Meru North -Kenya 2011

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AVERAGE ^{O}C	19.1	21.0	21.7	22.9	20.8	20.0	20.6	19.7	20.5	22.5	20.9	18.6
HIGH ^{O}F	66.4	69.8	71.1	73.2	69.4	68.0	69.1	67.5	68.9	72.5	69.6	65.3
AVERAGE LOW ^{O}C	17.2	17.7	18.4	16.4	16.9	14.8	13.5	15.2	17.2	16.6	16.0	17.2
LOW OF	63.0	63.9	65.1	61.5	62.4	58.6	56.35	59.4	63.0	61.9	60.8	62.3
RAINFALL(MM)	54.1	32.1	119.4	280.8	139.7	9.1	11.1	10.6	19.2	229.8	317.0	142.2
INCHES	2.13	1.272	4.701	11.055	5.5	0.358	0.437	0.417	0.756	9.047	12.48	5.6

Source: International Bio- Climate Classification System

Appendix X: Field Technicians Collecting Data

Appendix XI: The Principal Investigator Monitoring the Research Plots