DETERMINING QUANTITY OF COWPEA (*Vigna unguiculata*) LEAF YIELD UNDER DIFFERENT MANURE APPLICATION REGIMES AND CROPPING SYSTEMS IN WESTERN KENYA

BY

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DECLARATION

Declaration by the student

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DEDICATION

To my parents Valentine and Benter, my brothers and sisters who gave me moral support throughout my study. To my husband Paul and son Jerry, daughters Ruth and Williamma for their patience, support and prayers.

ABSTRACT

The low production of cereals and legumes among small-scale farmers in Kenya attributed to declining soil fertility and poor agronomic practices has led to renewed interest to review existing crop improvement technologies. Such technologies if applied appropriately can lead to crop yield improvement. The study was conducted among members of three farmer associations: MFAGRO (Vihiga), BUSSFFO (Bungoma) and AFDEP (Teso) in western Kenya, during the short rain season (SRS) and long rain season (LRS) of the year 2011 and 2012 respectively. The experiment aimed at studying factors affecting technology uptake among small-scale farmers. It also evaluated effect of fortified organic manure on leaf yield of cowpea grown under different cropping systems. The experimental design was split-split plot in a Randomized Complete Block Design (RCBD) with three replications per cropping zone (site). Two levels of organic manure: 0 t ha^{-1} and 5 t ha^{-1} (season one): 0 t ha $^{-1}$ and 2.5 t ha $^{-1}$ (season two) were randomized in the main plots. Three cropping systems: monocrop, conventional and Managing Beneficial Interaction in Legume Intercrops (MBILI) in the sub plots while two cowpea (Ken kunde, and Black eye) and two maize (Hybrid 513 and WS 303) varieties in the sub- sub plots. Topsoil (0-15 cm depth) was sampled and analysed for physical and chemical properties (pH, N, OC and P) before planting and after harvesting. Similarly, pH, N, and P of the organic manure were also analysed before fortification. Results showed that leaves of Ken kunde grown with fortified manure were vigorous and had a significantly high ($p <$ 0.001) leaf yield across all sites. Fortification of manure increased the levels of phosphorus and nitrogen available to the cowpea crop hence promoting growth of longer shoots, numerous, and larger leaves resulting in high leaf yield. Teso recorded (2.3 t ha-^{1}), Bungoma (1.9 t ha-^{1}) and Vihiga (1.8 t ha^{-1}) of total leaf yield. The least leaf yield (0.1 t ha^{-1}) was recorded in Black eye variety grown without manure in Vihiga. A significant difference ($p < 0.01$) in leaf yield was also observed in cowpea grown under different cropping systems. Ken-kunde grown in monocrop system recorded 1.9 t ha^{-} (Teso), 1.3 t ha^{-1} (Vihiga) and 1.5 t ha^{-1} (Bungoma). Ken-kunde grown in MBILI system recorded 1.7 t ha^{-} (Teso), 1.0 t ha^{-1} (Vihiga) and 1.2 t ha^{-1} (Bungoma).Same variety in conventional system recorded 0.9 t/ha (Teso), 0.7 t ha-^{1} (Vihiga) and 0.8 t ha^{-1} (Bungoma). Though Ken-kunde performed better while grown with fortified manure in monocrop system due to reduced competition, growing it with fortified manure in MBILI system was most appropriate to the small-scale farmer, because of farm size limitations and economies of scale associated with intercropping. The combination was recommended to farmers for adoption with an aim at improving cowpea leaf yield and associated income . The results also revealed that some of the factors that influenced adoption of technology and its intensity among small scale farmers included, site (county) where the farmer resided, know-how on value addition, knowledge on the technology, availability of inputs, age of household head and membership to a farmer association. It was also noted that ability of such farmers to identify farming related

problems and solutions required strengthening through capacity building. The community action research approach was therefore effectively used to engage farmers

through all the project phases thus increased their level of project ownership, technology adoption, adaptation and dissemination.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

AFDC	Angurai Farmers Development Cooperation
Al	Aluminum
ANOVA	Analysis of Variance
ARDAP	Appropriate Rural Development Agricultural Program
BUSSFO	Bungoma Small Scale Farmers Organization
C	Carbon
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CP1	Black eye cowpea variety
CP2	Ken Kunde cowpea variety
DAP	Diammonium Phosphate
FAO	Food and Agricultural Organization
Fe	Iron
FG	Farmer Group
FURP	Fertilizer Use Recommendation Project
H_2O	Water
H_2SO_4	Hydrogen Sulphate
KARI	Kenya Agricultural Research Institute
KBS	Kenya Berau of Standards
LM1-LM3	Low-Medium altitude zones
LR	Long rains
M.Sc	Master of Science

M2	Imazipar Resistant maize variety
MBILI	Managing Beneficial Interactions in Legume Intercrops
MI	Hybrid 513 maize variety
N	Nitrogen
P	Phosphorus
NH_4^+	Ammonium ions
NO_3^-	Nitrate ions
NPK	Nitrogen, Phosphorus, Potassium
pH	Negative logarithm of hydrogen ions
RCBD	Randomized Complete Block Design
SR	Short rains
UM1	Upper Medium zone 1
UM4	Upper Medium zone 4
USDA	United States Development Agency
WFP	World Food Programme
WG	Women Groups
WS303	Western Seed 303

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Sub-Saharan Africa (SSA), Kenya included, continues to experience food constraints. This largely contribute to poverty and poor health in rural set ups. While trying to improve the livelihoods of the rural populations in SSA, focus has been placed on “cause” and “effect” with little emphasis on “solutions” or “impacts” that innovative technologies might have on improving livelihoods in rural set-up (Ruto, 2008). Most of these technologies have existed and have been tested and have proved effective yet their rate of adoption is low.Some of the factors that influence adoption of technology and its intensity among small scale farmers include, site (county) where the farmer resides, know-how on value addition, knowledge on the particular technology, availability of inputs, age of household head and membership to a farmer association. Farmer participatory research approach was used and three farmer organizations; Bungoma small-scale farmers forum (BUSSFFO), Mwangaza farmers group (MFAGRO), Angurai farmers development program (AFDEP) and other stakeholders (input suppliers and marketing agencies) carried an exploratory study involving organized group discussions. The design, testing and implementation of a formal survey of association officers, members and non-members was carried out with assistance from a nongovernmental organization called Appropriate Rural Development in Agricultural Practices (ARDAP). The study took a community action research approach in order to involve all the stakeholders through the stages of need assessment, project implementation and evaluation. This was aimed at increasing rate of adoption and adaptation of the technologies in question by the farmers. Farmer-to-farmer extension approach was emphasized. This too gave a platform for the stakeholders to shift from outreach to engagement research .Results from the survey identified manure fortification and MBILI cropping system as some of available technologies which were seldom used by farmers. These were tested in field trials to determine the extent to which they would improve soil fertility, yield quantity and benefit-cost ratio of growing legumes in inter- crops.

Legumes are important because they supplement soil nitrogen through atmospheric fixation thus improving soil fertility (Tian *et al.,* 2000; Ojiem *et al.,* 2007).). Nutritive value of legumes make them a good supplement to diet based on cereals and root crops, which are very low in proteins and high in carbohydrates (IITA, 1999). They are generally cheaper than meat, fish and egg and are a source of locally available dietary protein, energy, minerals, vitamins and roughage for man and livestock (0kigbo, 1998; Abukutsa, 2011). Common legumes grown in Western Kenya are common beans, soya beans, green grams, groundnuts and cowpea.The specific legume whose production was addressed in this study was cowpea.

Cowpea *(Vigna unguiculata*) is a dual leguminous plant grown in most areas for its leaves and seeds. Although the leaf protein content is lower than that of the grain its dietary contribution is not negligible. Imungi and Porter (1983), have reported that Vitamin C and pro-vitamin are abundant in this vegetable leaves and it is also high in calcium, phosphorous and Iron. It is an important crop especially in the tropical and subtropical belt, where protein deficiency and malnutrition is a major problem (Abukutsa, 2011). It supplements protein in areas where animal protein consumption is rather low because of socio-economic constraints (Imungi *et al.,* 1983). The vegetable is becoming important in both urban and rural areas as an alternative to the common leafy vegetables such as cabbage (*Brassica oleracea* L.var.capitata), kale (*Brassica oleracea.* L.var Acephala) and spinach (*Spinacia oleracea*) due to changes in consumer behavior (Abukutsa, 2011).

There is much growing of cowpea in medium to low altitude areas as opposed to high potential areas (AATF/NGICA, 2006). Its growth characteristics make it a versatile crop adapted to a wide array of soils and moisture regimes. It too smoothers weeds and prevents soil erosion (Suh and Simbi, 1983). It fits in with different cropping systems, rotational regimes and marginal lands unsuitable for some of the major crops. It has expansive potential and offers opportunities for small-scale farmers to practice intensive cropping in their farms as a means of improving their income and food security (AATF/NGICA, 2006). It is cultivated in about 7.7 million ha worldwide of which about 6 million ha are in Africa (IITA, 1999).

1.2 Statement of the problem

Many technologies have been developed by Universities and National Agricultural Research Stations most of which have not been adopted by farmers. Some of these are the use of MBILI intercropping system and use of compost manure. The reason for low adoption has been said to be cost and labour intensiveness respectively. On the other hand the technologies have been introduced singly and at different times. There is need therefore to fine tune these technologies and repackage them in such a way that they can be used simultaneously as yield improvement tools. This is the reason for comparing MBILI alongside other cropping systems using cowpea and maize as test crops. Other than the ordinary compost the manure's nitrogen and phosphorus values too can be improved through fortification.

1.3 Justification:

Population pressure in Western Kenya is one of the main reasons leading to reduced land size per household. (FAO, 2011). This has resulted in conventional intercropping as a common practice in the region. This coupled with the use of low value organic manure has led to low maize and legume yields of less than 0.25 t/ha (Smaling *et al.,* 1993). A factor of major importance in performance of intercrops is their spatial arrangement. This affects edaphic interactions and light penetration into canopies of both the tall and short varieties (Ruto, 2008). Studies on MBILI have indicated a great potential of its spatial arrangement to improve both maize and legume yields (Tungani *et al*., 2002; Thuita, 2007). The system entails planting staggered two rows of a suitable legume and a cereal. The system allows for maximum light penetration, which is necessary for effective photosynthetic process for legumes and reduces competition for nutrients and water between maize and legumes (Tungani *et al.,* 2002; Woomer, 2007). Research has shown that inter cropping maize with beans or soybeans increases the farmer's returns by 83% and 70% respectively compared to planting the crops in the conventional or hill system (Tungani *et al.,* 2002; Woomer *et al.*, 2005). The MBILI system also enhances agronomic Phosphorus (P) and Nitrogen (N) use efficiency and uptake of these two important nutrients contributing to better growth and final yield. Most research work on MBILI systems have been carried out on maize intercropped with beans, soybeans or groundnuts. This study focuses on the fact that cowpea as a multipurpose legume can be intercropped with maize in MBILI system in order to widen the farmer's food preference and security. At present cowpea is the third most important pulse crop after beans *(Phaseolus vulgarism*) and green grams *(Cajanus cajan L, Nills'*) (Anah *et al*., 1997). The average cowpea yield ranges from 0.2-0.5 t/ha but has a potential of producing 4.0 t/ha (IITA, 1999). This low yield is due to poor soils and seeds, and inappropriate cropping system. (IITA, 1999). Report by the Ministry of agriculture (2012) indicates that area under cowpea production has increased from 85,510 ha in 2006 to 115,800 ha in 2011 but the average production stands at between 0.2 - 0.5 t/ha.

On the other hand, in the quest to identify nutrient limitations in legume-maize systems and solutions to the constraints, a nutrient replenishment technology was studied. This involved fortification of low value organic manure with phosphate and nitrogenous fertilizers to obtain 75 kg N/ha and 26 kg P/ha .Studies have shown that combination of manures and inorganic fertilizers have worked well towards replenishing N and P in poor soils (Okalebo *et al.*, 1999; Murwira *et al*., 2010) and improving growth and crop yield (Fujita *et al*., 1992; Palm *et al*., 2001). This is because each source of nutrients has a role to play in improving the physical chemical and biological soil condition. Adoption of these technologies is however low due to their labor intensive nature and inability of resource poor farmers to access or acquire the fertilizers and manures in time mainly after abolition of fertilizer subsidies imposed by structural adjustment programmers in Africa (Palm *et al*.,2001;Smaling *et al*.,1993). Most studies done in Western Kenya have focused on use of mineral fertilizers as opposed to organic manures (Hoekstra *et al*.,1995:Magesa *et al*.,2006) This study has therefore been designed to train farmers on improvement and use of available organic materials to replenish soil fertility. These can be crop remain or livestock wastes collected and allowed to decompose.

After which the value of these residues are improved using inorganic fertilizer as a means of compensating for losses incurred during decomposition. It also aims at improving production of high value legumes within appropriate cropping systems.

1.4 Objectives

1.4.1 Broad objective

To determine the leaf yield of cowpea grown under different manure application regimes and cropping systems among small scale farmers in Western Kenya.

Specific objectives

1. To identify socio-economic factors affecting technology adoption among small-scale farmers
2. To determine effect of fortified farmyard manure on growth and leaf yield of cowpea, in a MBILI system of intercrop.
3. To determine the Benefit-Cost Ratio of growing cowpea in different cropping systems.

1.5 Hypotheses

1.5.1 General hypothesis:

H_1; There is a significant difference in leaf yields of two cowpea varieties grown under different manure regimes and cropping systems.

1.5.2 Working hypothesis:

H_1; Socio-economic factors influences rate of technology uptake among small-scale farmers.

H_1; There is a difference in growth and leaf yield of cowpea as a result of addition of fortified farmyard manure in a MBILI system of intercrop.

H_1; There is a difference in Benefit-Cost Ratio when cowpea is grown in different cropping systems.

CHAPTER TWO

LITERATURE REVIEW

2.1 Food insecurity in Kenya

As an indicator of food insecurity in Kenya, 25% of the children are underweight (FAO, 2008). Consequently, there is increased commercial cereal import to bridge the food deficit (FAO, 2008). Nearly 75% of the rural house-holds are engaged in unproductive low input/low output subsistence farming (Kelly, 2003). On average 40% of the countries, households are food insecure throughout the year (FAO, 2008). As population pressure on agricultural land increases, fallow land becomes rare. This means reduced restoration of nutrients, inadequate improvements in soil physical conditions and incomplete suppression of weeds. The result is that soil fertility (SF) is further reduced and erosion damage increased resulting in poor crop production.A study of three counties of Bungoma Teso and Vihiga (sample counties) in Western Kenya was done and results used to explain some causes and effects of food insecurity in Kenya.

2.2 Technology adoption among small scale farmers.

In terms of relevance, the quantitative impact of technological packages adoption has been seldom studied, since most of the literature focuses on the impact of the adoption of specific technologies (Becerril & Abdulai, 2010; Dercon, 2009). The review of adoption studies by Feder and Zilberman (1985) indicated *inter alia*, that adoption decisions are influenced by a number of socioeconomic, demographic, ecological and institutional factors and are dependent on the technology. Studies of the key determinants of technology adoption by farmers growing upland rice and soybeans in Central-West Brazil (Strauss *et al.*, 1991) and to evaluate the role of human capital and other factors in adoption of reduced tillage technology in corn production (Rahm & Huffman, 1984) found that farmers' education and experience play a crucial role in facilitating technology adoption. Doss (2003) reported that the major reasons for not adopting farm-level technology in East Africa were: (1) farmers' lack of awareness of the improved technologies or a lack of information regarding potential benefits accruing from them; (2) the unavailability of improved technologies; and (3) unprofitable technologies, given the farmer's agro-ecological conditions and the complex set of constraints faced by farmers in allocating land and labour resources across farm and off-farm activities. The mismatch between technology characteristics and farmers' technology preferences was also responsible for low level of technology adoption in Ethiopia (Wale & Yallew, 2007). Other studies have revealed that off-farm incomes and availability of information influence technology adoption decisions through affecting risk aversion levels of smallholder farmers. Risk aversion level is likely to be negatively associated with adoption as farmers are less certain about the profitability (productivity) of new technologies when they use them for the first time. Farmer's level of risk aversion which is the function of their poverty level, lack of information on the productivity of the technology, and stability of the impact of the technology are all important factors (Kaguongo *et al.,*1997; Feder & Slade, 1984; Feder *et al.,* 1985; Kristjanson, 1987).

Putler and Zilberman (1988) revealed the importance of physical capital endowment in the adoption process. Physical capital commonly associated with adoption of technologies has been identified as farm size or cultivated land, livestock and farm implements owned (Feder &O'Mara, 1981; Rahm & Huffman, 1984; Shapiro, 1990; Nkonya *et al.,* 1997). A study in Mozambique revealed that some of the key factors affecting adoption of Orange Flesh Sweet Potato (OFSP) included availability of vines, intensity of extension service and number of times the respondent received vines (Mazuze, 2005).

One study in Western Kenyan, which evaluated the effect of women farmers' adoption of Orange Flesh Sweet Potato (OFSP) in raising Vitamin A intake, found that women farmers were likely to adopt the OFSP if the clones were sufficiently high in starch, low in fibre, and if they were introduced through community-level education programmes that focused on the health of young children (Hagenimana & Oyunga, 1999). To improve availability of relevant information for increasing adoption, many development agents have devised several approaches and innovations. When the innovation system (such as extension service) is linked to farmers to promote effective communication, identification, problem solving and personal interactions of a formal or informal nature, higher adoption of technology is likely (Steffey, 1995). Use of farmer associations as a focal point for technology dissemination can work well towards increasing rate and intensity of technology adoption.

2.3 Farmer Associations as agents of extension in Kenya.

Agricultural extension services are one of the most common forms of public-sector support for knowledge diffusion and learning. Extension has the potential of bridging discoveries (and mitigation methods) from research laboratories and the in-field practices of individual farmers. In addition to information about cropping techniques, optimal inputs use, high-yield varieties and prices, extension frontline agents can improve the managerial skills of farmers by diffusing information on record keeping, further improving the commercial potential of agricultural production (Birkhaeuser &Evenson, 1991). In Kenya, as of 2005, 61% of the population was employed within the agriculture sector (World Bank, 2013). At the same time, climate change is believed to affect adversely the highly productive lands, representing only 16% of the territory, that are subject to high and medium rainfalls. Those factors conjugated threaten rural household's livelihoods, income and food security for the country's poor, who represent a little over half of the population. In order to act upon the situation, the Government of Kenya has encouraged formation of the farmer association which collectively bargain for member farmers and address their needs.

They aim at uplifting productivity, encouraging commercialization and enhancing resilience through the increased use of agricultural technologies and improved inputs, using participatory agricultural extension approaches. More than 70% of the farmers interviewed during the initial survey claimed that being members of the farmer associations had led them to regard farming as a business rather than a way of surviving. Low levels of skills among members of the FAs'sometimes hamper the potential of the different extension programmes. Other reasons for the failure of the FAs' to enhance productivity include the lack of understanding on the incentives to adopt new technologies and whether they suit the socioeconomic and agro ecological circumstances of the service recipients (Birkhaeuser & Evenson, 1991). Farmers therefore need training and retraining on existing technologies for crop improvement as well as build their capacity on management skills (Plate 1). This can only be achieved when their rate of technology adoption and adaptation improves. The approach of community action research taken by this project aimed at increasing the rate of technology adoption and adaption. Most farmers being members of different

Farmer Associations (FA) training them through these associations would be most effective, because member training is normally an objective of most FA's. Use of technology in improving high value household crop production is an effective tool in addressing food insecurity. One such household legume crop is cowpea.

Plate 1: Farmers from vihiga sharing on crop improvement technologies during a field day

2.4 Cowpea production

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 continuous cropping with little or no additional soil fertility amelioration technologies. Phosphorous (P) and Nitrogen (N) are the most limiting soil nutrients (Kipkoech *et al*., 2010). Famers in the area, just like most African farmers, rarely can afford external inputs (Kipkoech *et al*., 2010). The most appropriate technologies for these farmers therefore, are those that require them to manipulate existing and affordable technologies to improve crop production. One such approach is the shifting to organic farming as a soil amelioration technology. Quality of such organic substances should be enhanced through fortification with inorganic fertilizers. Less quantity of such materials are therefore used in improving crop production (Ayoola *et al*., 2009). The other appropriate technology is Managing Beneficial Interaction in Legume Intercrops (MBILI) system. Here, two alternate rows of maize are staggered with two rows of a suitable legume, allowing for wider row spacing between the legume and the cereal.

The resultant wider rows are necessary for effective photosynthetic process for legumes. It also reduces competition for nutrients and water between the two crops, while maintaining the same plant populations (Woomer *et al*., 2004). The MBILI arrangement can improve legume yield and the total crop value by 12% without requiring additional investment by farmers or reducing the yield of maize (Rao *et al*., 2000, Tungani *et al.*, 2002). The choice of the legume intercropped with the maize plant depends on many factors such as farmer's preference and the purpose for which the legume is grown. One such crop that is suitable for the intercrop is cowpea. Cowpea has an ability to fix 75-150 kg N/ha under good conditions (Woomer *et al.*, 2004). However, in order to effectively fix nitrogen, the legume requires starter nitrogen, which aids in initial establishment of the crop. This can be supplied through application of organic manure or nitrogen and phosphorus based fertilizers (Okalebo *et al.*, 2006). The capacity of cowpea to fix nitrogen can also be improved through inoculation with *Bradyrhizobia* (Woomer *et al.*, 2004). Mixed cropping systems incorporating legumes such as cowpea can utilize the nitrates availed during fixation process in building up reserves for enhanced growth and production of associated crops (Ojiem *et al*., 2007). Cowpea productivity stands between 200 - 500 kg/ha among most scale farmers in Kenya (Table 2.1) a value that can be raised through improved agronomy.

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 (*Vigna unguiculata*) belongs to the *leguminosae* family. Some common varieties grown in Kenya are local brown and black- eye (with prolonged harvesting period and a finer texture) and the improved Ken Kunde (with high hybrid vigour but poor texture). The nutritive nature of cowpea leaves and seeds is shown on Table 2.2.

Table 2.2: Nutritional value of cowpea seeds and leaves

Nutrients	Dried seeds	Leaves
Water (ml)	11	85
Calories	338	44
Proteins (g)	225	4.5
Fat (g)	1.4	0.3
Carbohydrates (g)	61	8
Fiber (g)	2.0	5.4
Calcium (mg)	104	256
Phosphorous (mg)	416	63
Thiamine (mg)	0.08	0.20
Riboflavin	0.9	0.37
Niacin (mg)	4.0	2.1
Ascorbic Acid (mg)	2.0	56
Vitamin A (mg)	-	150

Source: Imungi et *al.*, 1983

2.4.1 Ecology

Cowpea is one of the more heat and drought tolerant legumes growing in areas with only 500 mm rainfall per annum. The longer podded varieties require high rainfall of up to 1500 mm per annum. Those grown for seeds have a critical period of high moisture requirement prior to flowering (Holland *et al.*, 1991). Cowpea performs well in a range of soils and soil conditions but performs best on well drained sandy soils with a pH range of 5.5-6.5 (Holland *et al.,* 1991). The crop tolerates a wide range of soil conditions including saline soils but it is sensitive to water logging.

2.4.2 Cultivation and Management

Cowpea can be grown either in pure stand or in mixture with other crops such as maize. They are grown from seeds , either broadcasted under mixed cropping or sown in rows 2.5 cm deep in, 40 cm apart with an inter crop spacing of 30 cm (Ruto,2008). Seed rates when broadcasted is 50-60 kg/ha ; 30-40 kg/ha when grown in pure stands. Cowpea grown as forage, cover crop or as green manure should be sown at a higher seed rate of 90-100 kg/ha (Ruto, 2008). The deep-rooted system and earliness in maturity are some of the factors that make cowpea adapted to hostile environment (Nzabi, 2000). Cowpea like other legumes forms symbiotic relationship with specific soil bacteria (*Rhizobium spp),* and fixes nitrogen in the soil (Ruto, 2008). Cowpea derives significant amount of nitrogen requirements from the atmosphere and may fix 75-150 kg N/ha for its benefit and the succeeding crop (Holland *et a*l., 1991; Mugendi *et al*., 2001). For growth of cowpeas in areas where it has not been grown recently, inoculation with N-fixing bacteria is beneficial. 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. It’s leaves and pods are picked at frequent intervals as, and when they mature (Ruto, 2008). An average yield of dry cowpea seed of 240 kg/ha and 400 kg/ha of leaves has been reported (USDA, 1995). Average yield of dry cowpea seeds under subsistence agriculture stands at 100-500 kg/ha. However under good management a yield potential of 3 t/ha of seeds and 4 t/ha of leaves can be achieved (USDA, 1995).

Supply of cowpea is determined by the yield obtained per season. Ministry of Agriculture report (2012) states that the area under cowpea production has progressively increased from 85,510 ha (2006) to 115,800 ha (2011). Despite this, the average yield has remained at between 0.2 t-0.5 t/ha. This primarily has resulted from lack of farm inputs, poor soils and agronomic practices. The use of high value manure, inoculation of certified seeds and appropriate cropping system can achieve a higher yield**.**

2.5 Land degradation and its influence on agricultural production

Most soils in Western Kenya, mainly the acrisols and the feralsols are of low fertility, limited water-holding capacity and are prone to erosion due to their sandy texture, high land use intensity and heavy rainstorms. Widespread N and P deficiencies in soils due to continuous cropping (Okalebo, 1996), high concentration of H^+,Al^{++},Fe^{++} and inability of smallholder farmers to invest on fertilizers to replace the lost nutrients (Okalebo, 1996 ; Lwayo *et al.*,1999) , have led to low agricultural productivity in the counties. Studies have shown that Al^+ toxicity inhibits root elongation and overall growth and yield of maize and cowpea (Kanyanjua *et al,* 2000; Ranamukhaarachi, 2005). The high population densities of 900 people or 294 households (or on average 8 persons) / km^2 has resulted in land subdivision into small units, further lowering agricultural productivity of the area (Shepherd *et al*, 1996; Swinkels *et al.,* 1997).

The problem of persistent low agricultural productivity in Western Kenya has resulted in a vicious cycle of continuous soil degradation and food insecurity. Crop yields have continued to decline despite the existence of a wealth of already developed technologies that farmers could use to improve soil fertility. In 1982 when the Ministry of Agriculture conducted fertilizer trials in various districts of western Kenya, maize yields in Vihiga increased from 3800 kg ha^{-1} (without addition of fertilizer) to 6100 kg ha^{-1} with addition of (60-60-0) NPK fertilizer. The highest maize yields of 14220 kg ha^{-1} with addition of 178 kg N and 104 kg P ha^{-1} was recorded. This high yield increase realized in the 1980's contrasts greatly with 1990's report of maize yields of on average 122 kg ha^{-1}, (Sanchez *et al*., 1997). This shows a drastic decline in land productivity in Western Kenya over the years. The role played by N and P in crop growth and development cannot be overlooked, hence restoring N and P to higher levels that maintains their availability over longer period is a capital investment; hence a need to identify a technology that can arrest the accelerated fertility depletion (Sanchez *et al*.,1997).

2.6 Soil condition improvement using fortified organic manure

Maintenance of high crop yields under intensive cultivation is possible only through the use of fertilizers. The use of inorganic fertilizers has not been helpful as it is associated with increased soil acidity and nutrient imbalance (Ayoola *et al.,* 2009; Ondieki *et al*., 2011). Inorganic fertilizers are usually not available and are always rather expensive for the low–income, small scale farmers (Kipkoech *et al* 2010).Organic manures, such as cow dung; poultry manure and crop residues can be used as an alternative for the inorganic fertilizers (Kumar *et al*.,2000). The need to use renewable forms of energy has revived the use of organic fertilizers worldwide.

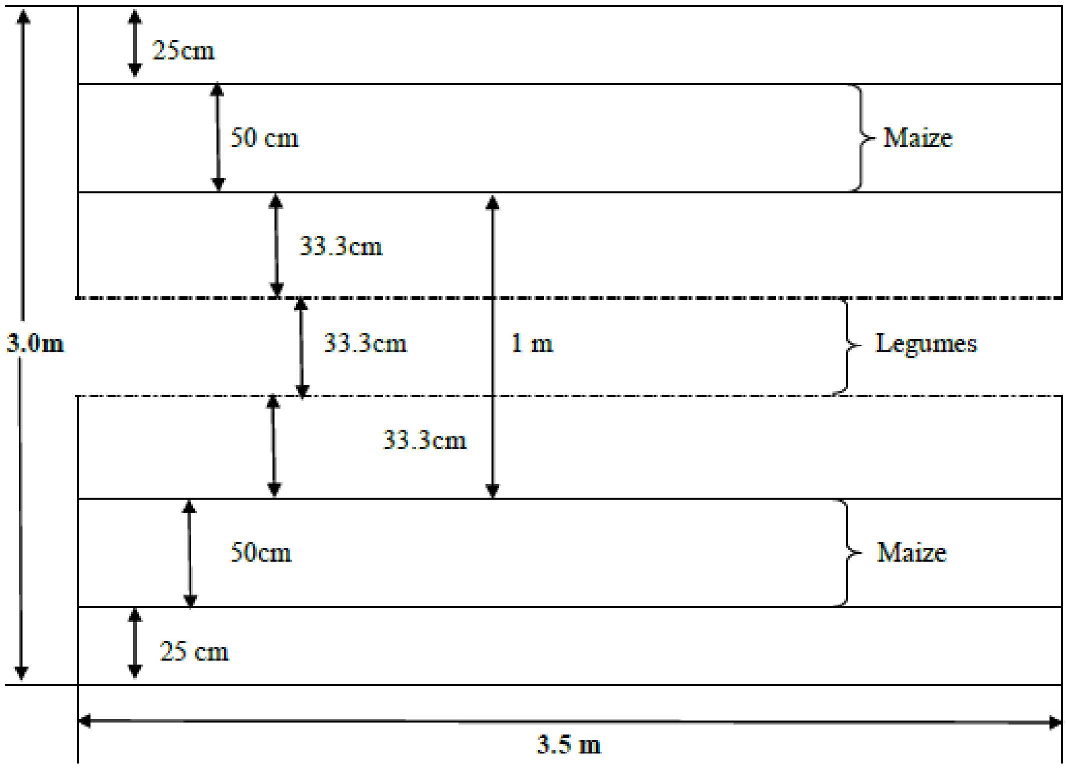
Application of organic manures sustains cropping systems through better nutrient recycling (Agbede *et al*., 2008; Ndungu *et al*., 2003). Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect supporting better root development, leading to higher crop yields (Ibewiro *et al.,* 2000; Suge *et al.,* 2011). Improvement of environmental conditions and public health as well as the need to reduce costs of fertilizing crops are also important reasons for advocating increased use of organic materials (Buresh *et al.,* 1997).

Application of organic manures plays a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization, thereby improving both the physical and the biological properties of the soil (Suge *et al.,* 2011). Organic manures decompose to give humus which plays an important role in the chemical behaviour of several metals in soils through the flavonic and humic acid contents, which have the ability to retain the metals in complex and chelate forms reducing their toxicities (Ayoola *et al*., 2009). The materials too can reduce the P sorption capacity of soil; solubilise P from insoluble Ca, Fe and Al phosphate thus increasing P availability (Agbede *et al.,* 2008). Besides enhancing P and organic materials, they too supply other nutrients especially N due to their high tissue concentration of the same (Agbede *et al.,* 2008). Organic materials too add carbon to the soil and provide substrate for microbial growth and subsequent activities. Soil pH and subsequent availability of nutrients too is influenced by addition of organic manure. Organic manures also improve the water holding capacity of the soil; improve the soil structure and the soil aeration. The benefits derivable from the use of organic materials have however not been fully utilized in the humid tropics (Ayoola *et* *al*., 2009). To meet crops' nutrient supply, organic fertilizers are, however, required in rather large quantities. Supply of nutrients from the organic materials can be complemented by enriching them with inorganic nutrients that will be released fast and utilized by crops to compensate for their late start in nutrient release.

2.7 Economic importance of maize-legume intercrops.

Maize-legume intercropping is widely practiced by farmers because they know it offers higher returns per unit area of land and less risk (Humpreys, 1995). Studies indicate that conventional intercropping makes 67% better use of the land than growing maize and legumes separately as in monocrop. Shifting from conventional to MBILI intercrop system results in additional 40% land use efficiency, an improvement that can make a huge difference in smallholders' food security, without additional investment in inputs. MBILI results in an overall income gain that can help meet farm families' hopes and expectations for a better life (Tungani *et al.,* 2002).

MBILI that aims at improving yields and returns of the legumes grown with maize is one of the available technologies but is seldom used by farmers. The basic approach is to stagger two rows of maize alternated with two rows of a suitable legume, allowing for better light penetration, which is necessary for effective photosynthetic process especially for legumes and reduces competition for nutrients and water between maize and legumes while continuing to maintain the same plant population (Woomer *et al*., 2004). Crops are sown at 0.50 m between two maize rows and 1 m between the maize and the intercropped cowpea rows.



S
ource:Woomer *et al.*, 2004

Fig. 2.1: A schematic representation of MBILI spatial arrangement (showing an intercrop with two rows of maize spaced at 50cms and two rows of a legume spaced at 33cms apart.The row spacing between maize and the legume is 1m)

The MBILI arrangement can improve legume yield and total crop value by 12% without requiring additional investment from farmers or reducing the yield of maize (Tungani *et al*., 2002). A study conducted by Ruto (2008) in Western Kenya showed that MBILI improved maize yield by 160 kg/ha. Legumes that require more sunlight, such as green gram and groundnut, performed particularly well when planted using MBILI. Farmers found it easier to weed and top-dress the legumes grown under this system in their fields (Woomer *et al*., 2004).

Tungani *et al*., (2002) conducted a field trial to compare yields in conventional and MBILI intercrops of maize and beans; green gram and groundnut with and without 150 kg DAP per ha. Included, as treatments were maize and legume monocrop to not only compare the two-intercrop systems, but to also calculate the overall advantages of intercropping over monocropping. Maize grown under the MBILI row arrangement performed slightly better (+158 kg per ha) than conventional intercropping. The conventional maize-bean intercrop without addition of DAP produced 775 kg of beans and 1196 kg of maize per ha, which were valued at KSh32, 600. Shifting to MBILI row arrangement increased crop value to KSh35, 800. In addition, combining MBILI and DAP fertilizer (costing KSh 4200) resulted in a Maize-bean intercrop worth KSh46, 900, an increase of 44 %! (Tungani *et al*., 2002).

On the other hand, ways should be found to help farmers to evaluate MBILI on part of their land (Woomer *et al*., 2004). Much of MBILI's economic advantage rests in the farmer's ability to grow high value legumes such as cowpea, groundnut and green gram. In addition, the MBILI approach may not out-perform conventional intercrops where maize yields are very high, because its advantage of providing more light to understory legumes becomes less as maize growth potential increases. The real test of the MBILI approach rests in its large-scale evaluation by farmers, and their willingness to adjust their cropping practices in terms of row arrangement and legume intercrop (Tungani *et al*., 2002). MBILI begins with the farmer's main enterprise, the maize-legume intercrop, and requires neither additional labor nor investment when practiced in its simplest form. It has been demonstrated that the MBILI planting arrangement can result in higher yields, considerable economic gain and more efficient use of land area (Tungani *et al*., 2002).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Approach

Farmer participatory research approach was used and three farmer organizations; Bungoma small-scale farmers forum (BUSSFFO), Mwangaza farmers group (MFAGRO), Angurai farmers development program (AFDEP) and other stakeholders (input suppliers and marketing agencies) carried an exploratory study involving organized group discussions. The design, testing and implementation of a formal survey of association officers, members and non-members was carried out with assistance from a nongovernmental organization called Appropriate Rural Development in Agricultural Practices (ARDAP). The study took a community action research approach in order to involve all the stakeholders through the stages of need assessment, project implementation and evaluation. This was aimed at increasing rate of adoption and adaptation of the technologies in question by the farmers. Farmer-to-farmer extension approach was emphasized. This too gave a platform for the stakeholders to shift from outreach to engagement research. Field trials were set using the Farmer association (FA) as the focal area to improve on technology uptake and dissemination. Exact locations of the field trials were Bumula (Bungoma), Sabatia (Vihiga) and Kolanya (Teso). Some of the proven crop yield improvement technologies were demonstrated side by side to enhance their adoption and adaptation. The technologies were tested in a multi location trial design and farmer's field's were replicates. Maize and cowpea were planted as test crops. Measurements obtained included crop height and yields; soil available mineral N, P, C and pH. Farmers together with the research group monitored and evaluated the trials continuously.

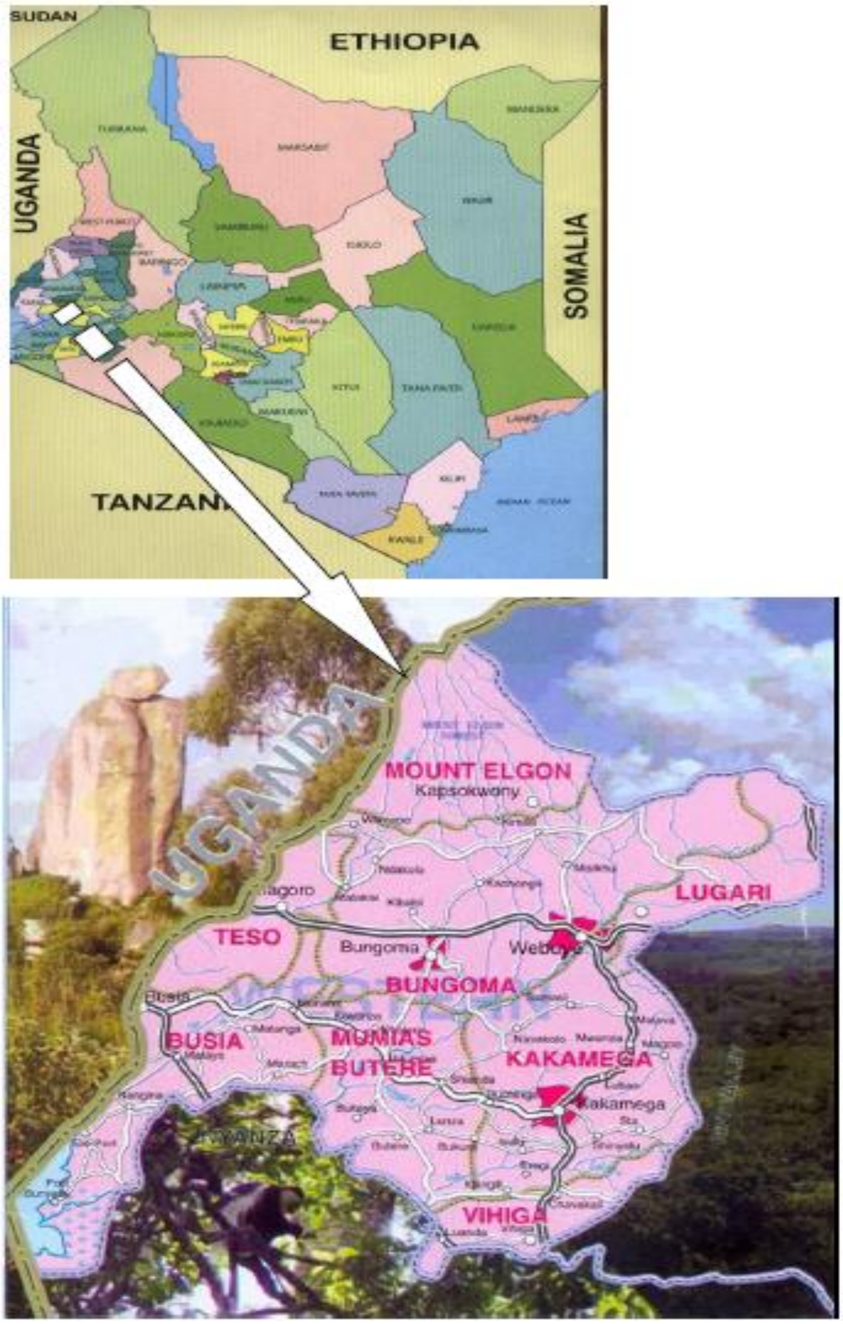
3.2 Description of study sites

3.2.1 Bungoma County

The altitude ranges from 2000 m above sea level around Mount Elgon to 1100 m at the minor valleys around the Nzoia River, which drains the major part of the county. The county has a bimodal rainfall pattern, with the first growing season (long rains) extending from March to August, and the second (short rains) from October to January. The county has generally abundant and well-distributed annual average rainfall of 1000-1800 mm. The temperature in the county ranges from about 20-22°C in the southern part of Bungoma to about 15-18°C on the slopes of Mount Elgon in the northern part of the district. Bungoma county falls under two major agro-ecological zones: the transitional upper midland zone (UM4) referred to as the maize-sunflower zone and the Lower Midland zones (LM1-LM3), which cover a greater proportion of the county (Jaetzold and Schmidt, 1983).

3.2.2 Teso sub- County

Located in Western province of Kenya and bordered by the Republic of Uganda to the west. The sub-county lies between latitude 0^{o} 29´ and 0^{o} 32´ North and longitudes 34^{o} 01´ and 34^{o} 07´ East. The sub-county's altitude ranges from 1,300m to 1500m above sea level. Most parts of the sub-county receive between 1270 mm and 2000 mm of annual rainfall whose distribution is bimodal. Temperatures for the whole sub-county are homogenous with annual mean maximum temperature ranging between 26^{o}C and 30^{o}C while the mean minimum temperature ranges between 14^{o}C and 22^{o}C (Jaetzold and Schmidt, 1983). Soils are well-drained acrisols and feralsols of sandy texture (GOK, 1997).



Source: Ministry of tourism and wildlife,Western Kenya region (2008)

Fig. 3.1 :Map showing study sites in western Kenya:Bungoma,Teso and Vihiga.

3.2.3 Vihiga County

Vihiga County is a high agricultural potential area predominantly (95%) in the upper midland (UM1) agro-ecological zone, with an altitude ranging between 1300 m to 1800 m above sea level, average temperatures of 20.3^{0}C and well drained soils that comprise dystric acrisols and humic nitrosols (Jaetzold and Schmidt, 1983). The area receives bimodal rainfall that ranges from 1800 - 2000 mm per year.

3.3 Farmer Associations (FA's)

Farmer associations were used as agents of extension. Considering the fact that many farmers belonged to the umbrella associations it was easier to reach them through the same. The following three farmer associations were identified from each county namely: Angurai Farmers Development Program me (AFDEP-Teso), Bungoma Small-Scale Farmers Forum (BUSSFFO-Bungoma) and Mwangaza Farmers Group (MFAGRO-Vihiga). The three contact farmers whose fields were used for trials were then identified from each of the above farmer associations.

3.3.1 Angurai Farmers Development Program (AFDEP)

This association was formed in September 2004. It is registered with the Department of Social Services and is intended to serve farmers in Teso sub-county. It is primarily composed of three self-help groups (Apokor, Atapara and Katakwa Women Groups), but is also recruiting individual members throughout Teso sub- county within the division of Angurai. The association has six office holders elected to one-year term. It maintains a small office in Angurai town. The association supplies inputs, buys and sells members produce to consumers and manufactures. It also organizes trainings for members.

3.3.2 Bungoma Small-Scale Farmers Forum (BUSSFFO)

This "umbrella" farmer association was launched in September 2004 and is comprised of 24 self-help groups and farmers field schools in Bungoma county. Many of the members also belong to the Smallholder Marketing Movement. BUSSFFO has seven office holders elected to one-year term. Among the officials, one has specific responsibility towards women and youth. The association has an office and “go-down” in Bungoma town. The association supplies inputs, buys and sells members produce to consumers and manufactures. It also organizes trainings for members and runs a table banking scheme to serve its members.

3.3.3 Mwangaza Farmers Group (MFAGRO)

It was launched in 2006 in order to fill in the gap left by the collapse of the Kenya Farmers Association and other cereal marketing cooperative societies. It consists of 102 farmer groups with over 900 members including the youth and vulnerable and operates a bank account. Its members attend various agricultural training courses. It benefits from the Vihiga Development Fund established by a consortium of NGOs and development organizations in Vihiga district. It works with several collaborators in agriculture and have a library with literature on a wide area. The association supplies inputs, buys and sells members produce to consumers and manufactures. It also organizes trainings for members and runs a table banking scheme to serve its members. The group faces the following challenges: access of farm inputs by resource poor farmers, and, access to legume and cereal processing tools to raise produce quality and reduce post-harvest losses.

3.4 Baseline and adoption surveys:

3.4.1 Survey design, sampling and data collection

Farmers were grouped into two: members and non FA members. Baseline and adoption survey data were collected for the purpose of impact assessment by comparing both members and non-member farmers before and after the programme implementation to compare their rate of technology uptake. The Baseline survey was conducted in February-March 2011 while the adoption survey was conducted in November-December 2012.

The sampling procedure for the survey, as described in Nkuba *et al.,* (2007), was a two-stage random sampling technique. The sampling framework was based on all the registered farmer associations in three counties in western Kenya, namely Vihiga, Bungoma and Busia. A total of three farmer associations were chosen, that is one association per county, the number being proportional to the number of farmer associations in each county. Lists of households were used to systematically select household members, in the FAs.

To obtain non-FA (controls) households, a list of all villages in the administrative locale where the selected FAs households were located was obtained. Two villages were then randomly selected in each locale. List of households in those villages were drawn up, and households randomly sampled. Information from the respondent was obtained using a standardised survey instrument. A total of 360 farmers were interviewed during the surveys, of which 180 were FA members and 180 were non-members in each study site. The total respondents were 1080. Baseline and adoption survey data were collected for the purpose of impact assessment by comparing both members and non-member farmers before and after the programme implementation to compare their rate of technology uptake. The Baseline survey was conducted February-March 2011 while the adoption survey was conducted in November-December 2012. Data was collected using two methods. The first method involved the use of structured questionnaires which had questions designed to different categories of respondents i.e. officials of the FAs, farmer groups and individual farmers. The second method used the Participatory Rural Appraisal which involved collecting information from different sources using semi structured interviews and transect walks. The method involved direct questioning, observations and making comparisons to validate the information. The do-it yourself approach which involved the focus groups interviews was also used. The same farmers in the baseline survey were targeted during the adoption survey.

The survey collected valuable information on several factors including household composition and characteristics, land and non-land farm assets, household membership in different rural institutions, varieties and area planted, costs of production, yield data for different crop types, household market participation, and household income sources. The survey also characterized the associations, support to farmers, identified promising soil fertility technologies and their adoption rates. Initial soil analysis outlined the soil fertility status of the study sites. Technology packages introduced to and tested by small-scale farmers were agreed upon in a participatory manner with the respective farmers and included lower-cost options that rely upon open- and self-pollinated crop varieties and the management of farmer-available manures and organic fertilizers. Information obtained from the survey guided the technologies that were identified and put on farm trials.

Survey data was analysed using SPSS software package (Norusis, 2005) and STATA programme (STATA, 2008). Descriptive statistics was used to organize, summarize and describe the data. Frequency distribution tools ordered arrangement of variables showing the number of occurrences in each category. Results were then worked out as percentages and displayed in tables.

3.5 Rainfall Data and Soil Sampling

Rainfall data for the year 2011 and 2012 was obtained from Kakamega and Bungoma meteorological centers and Malakisi tobacco leaf centre respectively (Appendices 15,16 and 17) Initial soil (0 - 15 cm depth) sampling was done before applying the treatments to characterize the study sites in terms of its fertility status (WRB, 2006). Composite soil samples weighing 500 g were obtained from each plot using the zig-zag sampling approach and taken for drying in the green house before laboratory analysis. The dried samples were crushed then sieved using 2mm and 0.25 mm screens for specific chemical and physical analysis in the laboratory. The soil pH was determined using a glass electrode pH meter in the general procedure for the soil pH (soil-water ratio of 1:2.5) according to Rhoades (1982) method. Available Phosphorus was determined by Olsen method as outlined by (Okalebo *et al*., 2002). Total nitrogen was determined by kjeldah oxidation method (Okalebo *et al*., 2002) and organic carbon by wet combustion oxidation method as outlined by Okalebo (1985). The particle size distribution was determined by Bouyoucus (1962) method. Soil sampling and analysis procedures were repeated at harvest to compare the results of soil chemical status before and after application and utilization of manure.

3.6 Field Experiment

3.6.1 Experimental Design

This was a split-split-plot experiment in a Randomized Complete Block Design (RCBD) with three replicates

3.6.2 Experimental Layout:

The experiments were mult-locational and farmer's field's were replicates. Three experimental sites were identified among members of the three FA's. The above sites were used during the SR's of 2011 and the LR's of 2012. Experimental fields were ploughed using ox drawn-plough and all weeds removed manually. The experiments were then laid on a 1008m^2 field. The experimental plot units were 10.5 m^{2}each block having 24 treatments replicated 3 times (Appendix 1). The treatments were randomly assigned to the three blocks. The experiments were carried out in two consecutive rainy seasons; 2011 SRs and 2012 LRs. During the 2011 SRs, the experiments consisted of twenty-four treatments replicated three times; two levels of farmyard manure (FYM; zero and five t ha^{-1}), two cowpea – Ken-kunde (CP2) and Black eye (CP1) and two maize varieties – H 513 (M1) and WS 303 (M2) grown under three cropping systems viz; - monocrop (mono maize and cowpea), conventional (conventional maize and cowpea) and MBILI (MBILI maize and cowpea). In the 2012 LRs, all other treatments remained the same except for the Farm-yard manure (FYM) that was fortified with different quantities of Triple Super Phosphate (TSP) and Calcium Ammonium Nitrate (CAN) depending on original manure quality, to raise N to 37.5 kg ha^{-1} and P to 26 kg ha^{-1}, respectively. The manure was then applied before planting and the treatments laid in a split-split-plot experiment in a Randomized Complete Block Design (RCBD) with three replicates. The main plot treatment consisted of the two levels of manure that was uniformly applied before planting. The three cropping systems were allocated to the sub plot while the four crop varieties were allocated to the sub-sub plot with each crop variety being laid in each of the three cropping systems. This gave 72 treatments (Appendix 1). Cowpea was sown at a rate of 10 kg ha^{-1} and maize at 20 kg ha^{-1} as per the treatments.

Table 3.1: Treatment combinations and their codes as administered in the three cropping system under the two fertility levels. Varieties; MI: Hybrid 513 (farmers maize seed), M2: WS 303 (striga tolerant maize seed), CP1: Black cowpea (farmers cowpea' seed), CP2: Ken-Kunde (improved cowpea seed))

TREATMENT	**CODES**	
FERTILITY	WITH MANURE (MANURED)	WITHOUT MANURE (CONTROL)
MONOCROP	M1	M1
	M2	M2
	CP1	CP1
	CP2	CP2
MBILI	M1CP1	M1CP1
	M1CP2	M1CP2
	M2CP1	M2CP1
	M2CP2	M2CP2
CONVENTIONAL	M1CP1	M1CP1
	M1CP2	M1CP2
	M2CP1	M2CP1
	M2CP2	M2CP2

The experiment principally investigated level of farmyard manure responses during the cropping season and its interactions with the two maize and two cowpea varieties grown under different cropping systems.

3.7 Preparation and use of fortified farm yard manure

In both seasons, the participating farmers prepared Farmyard manure (FYM). Organic manure obtained from the domestic animals was collected and heaped under a shade. Turning was done fortnightly while observing decomposition indicators. When ready the manure was solarised to destroy soil borne pests. A sample of the manure was obtained and dried in the green house for chemical analysis. The dried manure was ground to pass through a 0.5 mm sieve. Quality parameters of the manures i.e. total N, Available P and pH were determined and used at the recommended rates of 4 t - 5 t/ha in season I. In season II, the manures were tested for total N, Available P and pH and fortified close to FURP (1994) rates with Triple Super Phosphate (TSP) of between 50-60 kg ton^{-1} and Calcium Ammonium Nitrate (CAN) of between 100-150 kg ton^{-1} to raise the N content to 37.5 kg ha^{-1} and P level to 26 kg ha^{-1} (Plate 2) and used at a rate of 2.5 t ha^{-1}. Amount of inorganic fertilizer used was based on the initial N and P values of the manure.

Plate 2: Organic manure fortified with TSP and CAN

3.8 Planting and Management of the field experiment

The treatments were applied to each plot throughout the cropping seasons. In season one and two 5.0 t ha^{-1} and 2.5 t ha^{-1} of farmyard manure were broadcasted respectively to marked plots before planting. Cowpea seeds were inoculated using *Rhizobia spp* of bacteria (biofix) as per the instructions on the package (Plate 3). Planting was then done as per the treatments. The first hand weeding was done three weeks after planting, followed by top dressing by CAN at the rate 37.5 kg N ha^{-1}. There was an additional weeding two weeks later, which was stopped when the cowpea were nearing flowering. Harvesting of cowpea started one and a half months after planting and this continued at an interval of two weeks for one month. Spraying against insect pests and diseases was done mainly against aphids and stalk-borer . Ridomil (50 g/20 l of water) was used to manage fungal diseases while Duduthrin (10 ml/20 l of water) was used against pest infestation.

Plate 3: Certified cowpea seeds inoculated with *Rhizobia*

3.9 Data collection and analysis:

3.9.1 Identification of sample plants

Each plot had five rows of maize and four rows of cowpea except for cowpea mono that had eight rows of plants. Ten plants were chosen at random per plot i.e. two per row and tagged. Guard rows plants were omitted. The tagged plants were used for measurements of the different parameters.

3.9.2 Data scored

The growth and yield parameters including shoot length, leaf size, leaf fresh and dry weights were observed and recorded.

3.9.3 Shoot length and leaf area measurements

Shoot length and leaf area measurements were taken 6 weeks after emergence up to 10th week. The shoot lengths were determined on tagged plants by using a meter rule. It involved taking the length of the fresh vegetative shoot from the stem base to growing shoot apex and width and length of leaves (Plate 4). Leaf area (cm^2) was calculated as the product of the length and breadth at the broadest point of the longest leaf on the plant (Abukutsa, 2011).

Plate 4:A technician recording cowpea heights with the help of a farmer.

Calculations: Leaf Area Index (LAI) = (Leaf area (LA) x n) cm^2: where n is number of ridges; while Leaf Area Index = {(Laminal length x maximum width) 0.75} cm

3.9.4 Cowpea leaf yield measurement (above ground components)

The plants were uprooted from the effective area three months after sowing, population taken and total fresh weight taken. The pods were then picked by hand and the total fresh weight of tops (residue) taken. To get a sample legume residue, 15 plants were sampled in each plot; chopped, fresh weight recorded and packed in labeled khaki bags for drying and recording of dry weight.

Cowpea leaf yield t/ha

$$= \frac{\text{Sample dry leaf weight (t)}}{\text{Sample fresh leaf weight (t)}} \times \text{Total leaf weight (t)} \times \frac{10{,}000\text{m}^2}{7.5\text{m}^2}$$

3.9.5 Data analysis

The field experimental data was analyzed using ANOVA and treatment means compared using Turkey's honest significance difference.

3.9.6 Statistical model for the above design is indicated below

$$Y_{ijkl} = \mu + \beta_i + \alpha j + \varepsilon_{(ij)} + \lambda_k + \alpha\lambda_{jk} + \varepsilon_{ik(j)} + \omega_l + \alpha\omega_{jl} + \lambda\omega_{kl} + \alpha\lambda\omega_{jkl} + \varepsilon_{il(jk)}$$

Where

Y_{ijkl} : Total observation

μ:Overal mean

$\beta_{i:}$ Effect of i^{th} Replicate

αj : : Effect of j^{th} whole plot

$\varepsilon_{(ij)}$: Error due to i^{th} Replicate, j^{th} whole plot interaction

λ_k : : Effect of k^{th} sub-plot

$\alpha\lambda_{jk}$: Interaction effect of j^{th} whole plot and k^{th} sub-plot

$\varepsilon_{ik(j)}$: Error due to i^{th} Replicate, k^{th} sub-plot interaction in every j^{th} whole plot

ω_l : Effect of l^{th} sub- sub plot

$\alpha\omega_{jl}$: Interaction effect of j^{th} whole plot and l^{th} sub-sub plot

$\lambda\omega_{kl}$: Interaction effect of k^{th} sub- plot and l^{th} sub-sub plot

$\alpha\lambda\omega_{jkl}$: : Interaction effect of j^{th} whole plot , k^{th} sub-plot and l^{th} sub-sub plot

$\varepsilon_{il(jk)}$: Error due to i^{th} Replicate, l^{th} sub-sub plot interaction in every j^{th} whole plot and k^{th} sub-plot

3.10 Cost -Benefit analysis

The Cost Benefit analysis was done to determine the cost -benefit ratio (CBR) and the net- benefit resulting from growing cowpea under different cropping systems and manure regimes. The net benefit of each treatment was computed using partial budget of each treatment. This included costs and benefits which varied from the control (Opala *et al.*,2010). The change in leaf yield from that obtained under control was assumed to have resulted from growing cowpea using manure under different cropping systems (Ashilenje *et al*.,2011). The sale price of cowpea leaves was obtained from the vegetable vendors across the three counties and averaged. Costs of seeds and fertilizers were based on the prices offered by the FA's because they were the input supplier. Costs of labour and transport were based on the localy charged prices. The total added cost was subtracted from the total added revenue as a result of extra output which had resulted from use of manure and different cropping systems (over the control). The CBR was got by dividing the net benefit due to increased leaf yield over control by increased cost due to use of manure and different cropping systems (Ashilenje *et al*., 2011)

CHAPTER FOUR

RESULTS

4.1 Technologies identified during survey and factors influencing their adoption

Data obtained from the respondents in the survey showed that few farmers were aware of the existing technologies.The project had intended to promote the following technologies: Ua kayongo maize (Imazipar-resistant maize), MBILI system, Fortified manure, seed inoculation and legume processing (value addition) tools. Of the 1080 total respondents, 37.5 % knew about Ua Kayongo while 43.5 % knew very little. 45.3 % knew about fortified manure while 43.3 % knew very little. 42.1 % knew about the MBILI system while 52 % knew very little. 50.8 % knew about the legume processing tools while 40.8 % knew very little. 34.9 % knew about seed inoculation while 56.7 % knew very little (Table 4.1).

In all the sites 38.2% of respondents had adopted the available technologies, with 61.8 % of 1080 households having not adopted. 33.9 % of 360 households adopted in Bungoma, 41.8 % in Teso and 35.6 % in Vihiga, respectively. The level of technology adoption in the three counties was very low among both members and non members of farmer associations.Bungoma with an FA membership of 58.9 % had 33.9 % adopters. Teso with a membership of 61.6 % had 41.8 % adopters while Vihiga with a membership of 89.0 % had 35.6 % adopters respectively (Table 4.2).

Most adopters were from Teso (41.8 %) followed by Vihiga (35.6 %) while only 33.9 % of adopters were from Bungoma county (Table 4.2). About 37.4 % of household head were female while 62.3 % were male and there was a significant difference between adopters and non-adopters by gender. Households with large farm sizes were also not statistically different between adopters and non-adopters. The mean age of non-adopters was slightly higher than that of adopters but the difference was not statistically significant. The knowledge of existence of the various technologies for adopters was significantly higher than that of non-adopters indicating possible association between pre-requisite knowledge and adoption of technologies. The other significantly different attribute between adopters and non adopters was access to inputs (Table 4.3).

Table 4.1: Technologies available and the level of knowledge among the respondents

No.	Technology	% of famer know how		
		Know so much	Fairly know	Know very little
1	Ua Kayongo	37.5	9	43.5
2	MBILI	42.1	9	52
3	DAP	73.2	2	24.6
4	Fortified compost	45.8	11	43.3
5	Push pull	33.9	8	58.2
6	Lablab	22	7.5	60.5
7	Super two	35.4	6	58.7
8	Legume processing tools	50.8	8.5	40.8
9	Seed inoculation	34.9	8.5	56.7
10	Top dress	43.5	3.5	53
11	Lime	54.7	3	31.3
12	Foliar fertilizers	34.7	4.5	62.8
13	FYM	44.5	8	47.6

Table 4.2: Adoption of the technologies by site in the three counties of Western Kenya

GROUPS	SITES	BUNGOMA	TESO	VIHIGA	TOTAL
ADOPTION (%)	NON-ADOPTERS	66.1	58.2	64.4	61.8
	ADOPTERS	33.9	41.8	35.6	38.2
FA MEMBERSHIP (%)	NON MEMBERS	41.1	38.4	11.0	39.7
	MEMBERS	58.9	61.6	89.0	60.3
SAMPLE SIZE		360	360	360	1080

Table 4.3: Summary of characteristics of adopters and non-adopters of identified technologies in different study sites in Western Kenya. hh: head of household

CHARACTERISTICS	**ADOPTION (%)**	
	Non-adopters	Adopters
Site: Bungoma	35.3	26.0
Teso	30.8	32.1
Vihiga	33.9	31.9
Membership:Non-members	56.9	38.6
Members	43.1	61.4
Gender of hh:Male	62.6	71.1
Female	37.4	28.8
Age of hh :Mean	48.93	42.7
Standard deviation	13.82	12.3
Knowledge on technologies: Mean	6.65	7.62
Standard deviation	4.16	4.24
Area of land: Mean	0.20	0.17
Standard deviation	0.23	0.25
Access to inputs: Mean	3.08	3.43
Standard deviation	1.36	1.51

CHARACTERISTICS	ADOPTION (%)	
Sample size	680	400

4.2 Characteristics of Farm yard manure (FYM) used in the study

The samples of manure used in both seasons had neutral pH (around 7) which was good but had nitrogen levels below 1.5 % and P below 10mg/kg thus were of low quality. Manure used in Bungoma had 0.965 % N and 0.484 P mg/kg, Teso had 0.665 % N and0.462 P mg/kg while Vihiga had 0.965 % N and 0.484 P mg/kg in season one. In season II, Bungoma had 0.852 % N, 0.522 P mg/kg, Teso 0.941 % N, 0.635 P mg/kg while Vihiga had 0.732 % N, and 0.764 P mg/kg (Table 4.4).

Table 4.4: Chemical analysis of manure from different sites used during 2011SRS & 2012LR

Ordinary manure		Manure contents		
Season	Region	% N	P (mg/kg)	pH(1:2.5)
I	Bungoma	0.965	0.484	7.08
	Teso	0.665	0.462	7.12
II	Vihiga	0.659	0.434	7.33
	Bungoma	0.852	0.522	7.04
	Teso	0.941	0.635	7.33
	Vihiga	0.732	0.764	7.21
Fortified manure				
II	Bungoma	2.42	3.38	6.63
	Teso	2.55	3.94	6.94
	Vihiga	2.13	3.13	6.71

4.3 Changes in soil chemical characteristics as a result of manure application

The magnitudes and patterns ofchemical changes in soil in (0-15 cm depth) was recorded across all sites and seasons. An increase in soil pH (Bungoma 4.36 to 5.3; Teso 5 to 5.6; Vihiga 4.72 to 5.0) was observed across all the sites at the end of the first season. Total nitrogen (Bungoma 0.049 to 0.06;Teso 0.013 to 0.05;Vihiga 0.031 to 01.) and available phosphorus (Bungoma 3.3 to 4.3;Teso 3.0 to 3.8;Vihiga 2.28 to 4.6) levels too incresed at the end of the first season across all the sites. Bungoma soils were sandy loam,Teso were sandy loam while Vihiga were sandy loam (Table 4.5).

Table 4.5: Selected soil chemical and physical properties of the surface (0-15cm) (soils taken before planting during short rain season (2011) from the three farms in Western Kenya

Season 1									
Soil Parameter	**Regions**								
	Bungoma			**Teso**			**Vihiga**		
	initial	**control**	**manured**	**initial**	**control**	**manured**	**initial**	**control**	**manured**
%N	.049	.04	.06	.013	.03	0.05	.031	.02	0.1
P(mg/kg)	3.3	2.7	4.3	0.09	3	3.8	2.28	2.9	4.6
%c	0.74	1.5	1.7	0.32	1	1.9	1.34	1.8	2.4
pH (1:2.5)	4.36	4.8	5.3	5	5.2	5.6	4.72	4.9	5.0
% Clay	12			4			12		
% Sand	69			85			67		
% Silt	19			11			21		

Textural class	Sandy Loam	Sandy loam	Sandy loam

At the end of season two, an increase in soil pH (Bungoma 4.36 to 6.3; Teso 5 to 6.1; Vihiga 4.72 to 5.2) was observed. Total nitrogen increased (Bungoma 0.049 to 0.22;Teso 0.013 to 0.21;Vihiga 0.031 to 0.18) and Available phosphorus (Bungoma 3.3 to 14.1;Teso 3.0 to13,5;Vihiga 2.28 to 10.6) also increased at the end of the second season. Bungoma soils were sandy loams, Teso's were sandy loam while Vihiga's too were sandy loam (Table 4.6).

Table 4.6: Selected soil chemical and physical properties of the surface (0-15cm) (soils taken after planting during long rain season (2012) from the three farms in Western Kenya)

Season 2									
Soil Parameter	**Regions**								
	Bungoma			**Teso**			**Vihiga**		
	initial	**control**	**manured**	**initial**	**control**	**manured**	**initial**	**control**	**manured**
%N	.049	.07	0.22	.013	.03	.21	.031	.04	.18
P(mg/kg)	3.3	4.1	14.1	0.09	3.5	13.5	2.28	4.9	10.6
%c	0.74	1.0	2.6	0.32	0.7	2.5	1.34	1	2.6
pH (1:2.5)	4.36	5.5	6.3	5	4.8	6.1	4.72	4.9	5.2
% Clay	12			4			12		
% Sand	69			85			67		
% Silt	19			11			21		
Textural class	Sandy Loam			Sandy loam			Sandy loam		

4.4 Changes in growth of the two cowpea varieties grown in the three sites as a result of manure application during short rain season (2011) and long rain season (2012)

4.4.1 Shoot lengths

Cowpea shoot lengths were recorded for six weeks at an interval of two weeks to monitor the differences in lengths hence growth rate as affected by manure. A small difference was observed in average shoot length between the two varieties across all the sites in season season 1 . Teso and Vihiga recorded average shoot lengths of 40 cm in Ken kunde (CP 2) grown with ordinary manure with the least average shoot length (20 cm) being recorded in the Black eye control in Bungoma (Fig.4.1:Appendix 7). There was a significant difference between the cowpea varieties in terms of shoot lengths across all the sites in season 2. Teso recorded an average shoot length of 60 cm in Ken kunde grown with fortified manure with the least average shoot length (20 cm) being recorded in the Black eye control in Vihiga (Fig.4.1:Appendix 8).

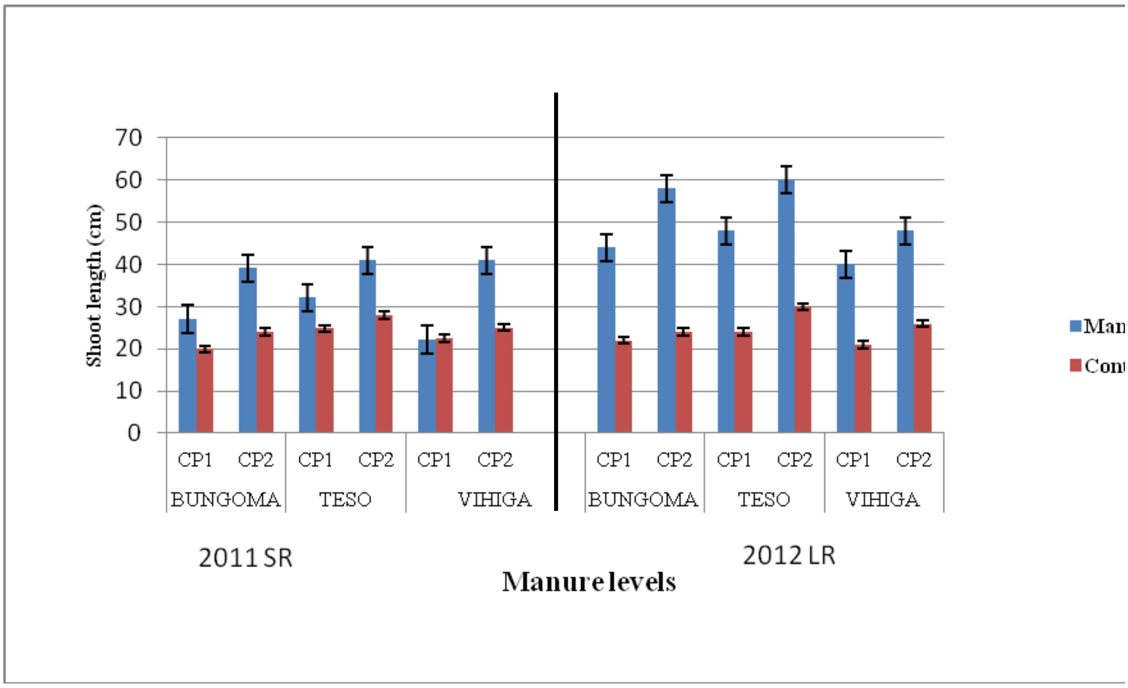


Fig.4.1: Effect of manure application on average shoot lengths of the two cowpea varieties grown in the three sites during short rain season (2011) and long rain season (2012) with manure. CP1;Black-eye : CP2;Ken-kunde. Error bars represents standard error of the difference of means

4.4.2 Leaf Area (LA)

Cowpea leaf area (LA) was recorded for six weeks at an interval of two weeks to monitor the differences in leaf area index (LAI) hence growth rate as affected by manure. A small difference was observed in leaf area index between varieties grown within same site in season 1 (Fig.4.2 ; Appendix 9). There was a significant difference between the cowpea varieties in terms of plant leaf size across all the sites. The highest average leaf area (ALA) of 1.38 cm^2 was recorded in Black eye (CP1) grown with fortified manure in Teso with the least ALA (0.7 cm^2) being recorded in the Ken kunde control in Vihiga in season 2 (Fig.4.2 ; Appendix 10). Ken kunde gave a higher yield of smaller leaves compared to Black eye.

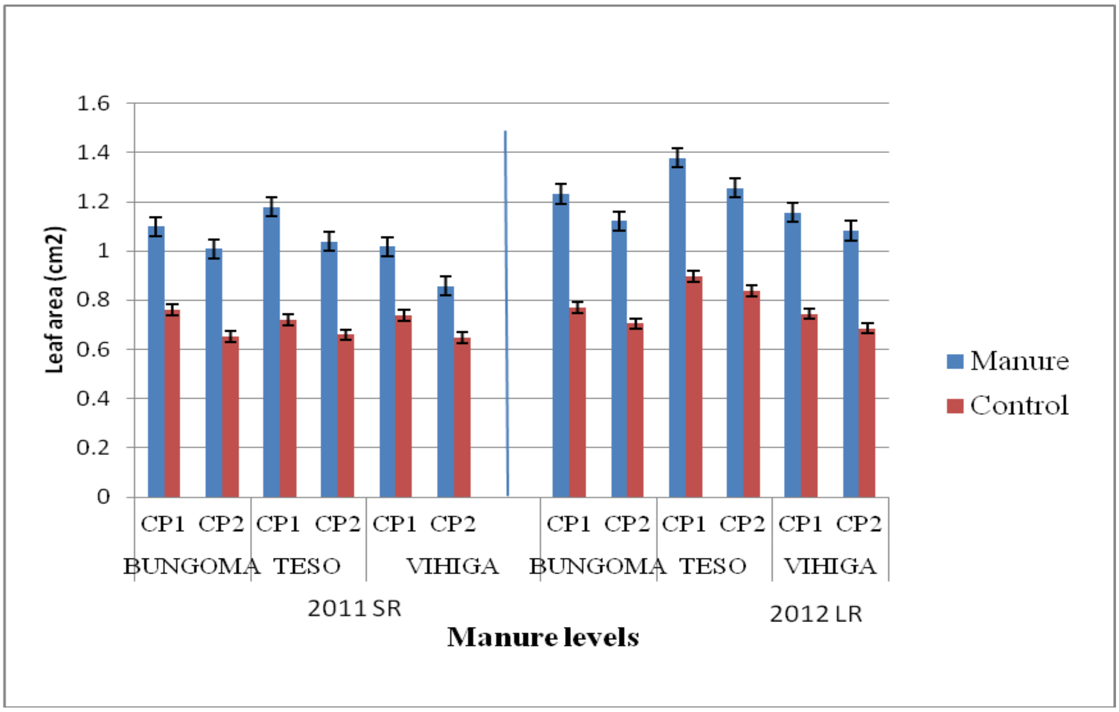


Fig.4.2: Effect of manure application on leaf area

(of the two cowpea varieties from the three sites during short rain season (2011) and long rain season (2012) with manure. CP1;Black-eye :CP2;Ken-kunde . Error bars represents standard error of the difference of means)

4.5 Changes in the leaf yield (t/ha) of the two cowpea varieties grown in the three sites as a result of manure application during short rain season (2011)

There was a small difference in yield between the two cowpea varieties grown with ordinary manure and the control across all sites. Ken-kunde grown with ordinary manure recorded a yield of (Teso 0.34 t/ha;Bungoma 0.3 t/ha ;Vihiga 0.23 t/ha). Black-eye grown with ordinary manure recorded a yield of (Teso 0.2 t/ha;Bungoma 0.26 t/ha ;Vihiga 0.11 t/ha). The highest leaf yield (0.34 t/ha) was recorded in Ken kunde variety grown with ordinary manure in Teso while the least leaf yield (0.05 t/ha) was recorded in Black eye variety grown without manure in Vihiga (Table 4.7).

Table 4.7: Effect of ordinary manure application on leaf yield (t/ha) of the two cowpea varieties grown in the three sites during short rain season (2011). CP1;Black-eye: CP2;Ken-kunde.Ns; not significant. p ≤ 0.5; the probability at or less than 5%

SEASON	SITE	VARIETY	NUTRIENT		MEAN		
			Control	Manured	(a)	(b)	(c)
		CP1	0.1006	0.2603	0.18045		
	BNG	CP2	0.1286	0.3056	0.2171	0.1987	
		CP1	0.161	0.263	0.212		
	TESO	CP2	0.255	0.345	0.3	0.256	
		CP1	0.0573	0.1143	0.0858		
I (2011)	VIHIGA	CP2	0.1053	0.233	0.16915	0.1274	0.194
MEAN			0.1346333	0.253533	0.194083	0.194083	

Standard error of the difference (SED)	**Probability for F test (p < 0.05)**
SED Nutrient (Nut) level : Ns	Nutrient level : 0.07
SED Variety (Var) :Ns	Variety : 0.241
SED Site (Si) : Ns	Site: 0.01
SED Nut x Var :Ns	Nut x Var : 0.872
SED Nut x Var x Si : Ns	Nut x Var x Si: 0.9

The fortified organic manure used in the second season had a highly significant interaction ($p < 0.001$) with both cowpea varieties resulting in a positive increase in leaf yield across all the sites (Table 4.8). Ken-kunde grown with manure recorded a yield increase (Teso 0.34 t/ha to 2.3 t/ha;Bungoma 0.3 t/ha to 1.92 t/ha;Vihiga 0.23 t/ha to 1.7 t/ha) in season two. Black-eye grown with manure recorded a yield increase (Teso 0.2 t/ha to 1.8 t/ha;Bungoma 0.26 t/ha to 1.7 t/ha;Vihiga 0.11 t/ha to 1.6 t/ha) in season two.The highest leaf yield (2.3 t/ha) was recorded in Ken kunde variety grown with fortified manure in Teso while the least leaf yield (0.1 t/ha) was recorded in Black eye variety grown without manure in Vihiga in (Table 4.8).The leaf yields per site too were significantly different ($p < 0.001$). Teso gave a mean leaf yield of 1.406 t/ha,Bungoma 1.399 t/ha while Vihiga's was 1.059 t/ha.

Table 4.8: Effect of fortified manure application on leaf yield (t/ha) (of the two cowpea varieties grown in the three sites during long rain season (2012). CP1;Black-eye: CP2;Ken-kunde. .Ns; not significant. p ≤ 0.5; the probability at or less than 5 %)

SEASON	SITE	VARIETY	NUTRIENT		MEAN		
			Control	Manured	(a)	(b)	(c)
	BUNGOMA	CP1	0.9266	1.7033	1.31495		
		CP2	1.076	1.92	1.498	1.399	
	TESO	CP1	0.6366	1.82	1.2283		
		CP2	0.8266	2.316	1.5713	1.406	
	VIHIGA	CP1	0.3766	1.643	1.0098		
II (2012)		CP2	0.4733	1.746	1.10965	1.059	1.2886
MEAN			0.7192	1.857	1.2886	1.2886	

Standard error of the difference (SED)		Probability for F test (p < 0.05)
SED Nutrient (Nut) level	:0.04	Nutrient level: 0.001
SED Variety (Var)	:0.04	Variety : 0.004
SED Site (Si)	:0.06	Site: 0.01
SED Nut x Var	:Ns	Nut x Var : 0.005
SED Nut x Var x Si :	:NS	Nut x Var x Si: 0.3

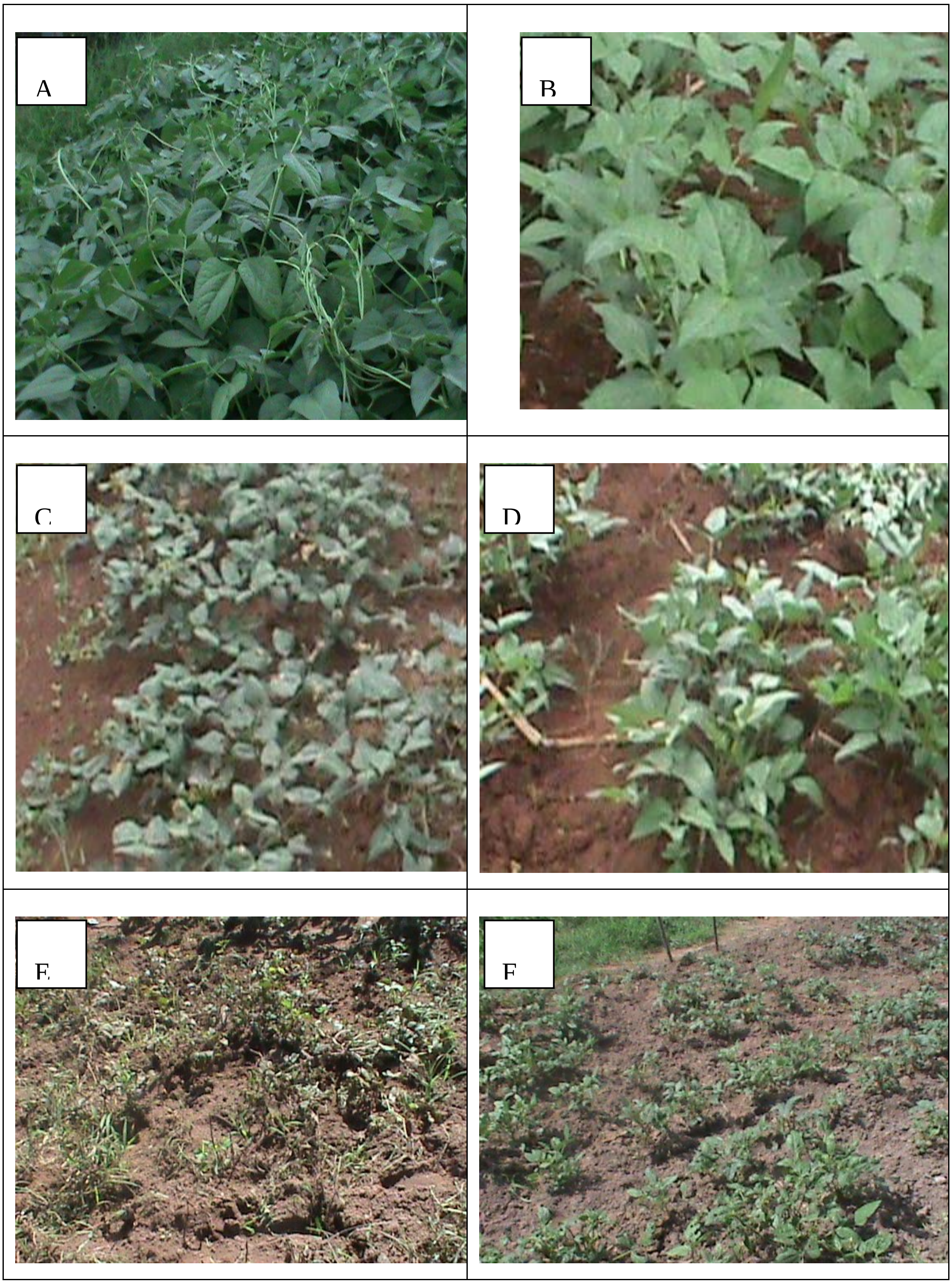


Plate 5: Cowpea varieties grown with different fertilizer types in Bungoma. A and B, Ken kunde and Black-eye grown with fortified manure. C and D, Ken kunde and Black-eye grown with ordinary manure. E and F, Ken kunde and Black-eye grown without manure.

4.6 Changes in growth of the two cowpea varieties in the three sites as a result of cropping systems during first rain season (2011) and second rain season (2012)

4.6.1 Shoot lengths

Cowpea shoot lengths were recorded for six weeks at an interval of two weeks to monitor the differences hence growth rate as affected by cropping systems. There was a small difference in interaction between systems and the varieties resulting in a small increase in shoot lengths across all the sites in season I. Teso's longest average shoot measured 24 cm in Ken kunde grown with ordinary manure while the least length of 15 cm in Black eye control was recorded in Bungoma in season I. There was a significant difference in interaction between systems and the varieties resulting in an increase in shoot lengths across all the sites In season II .Teso recorded an average shoot length of 38 cm in Ken kunde grown in monocrop system and the least shoot length of 15 cm recorded in Black eye control in Bungoma (Fig 4.3).

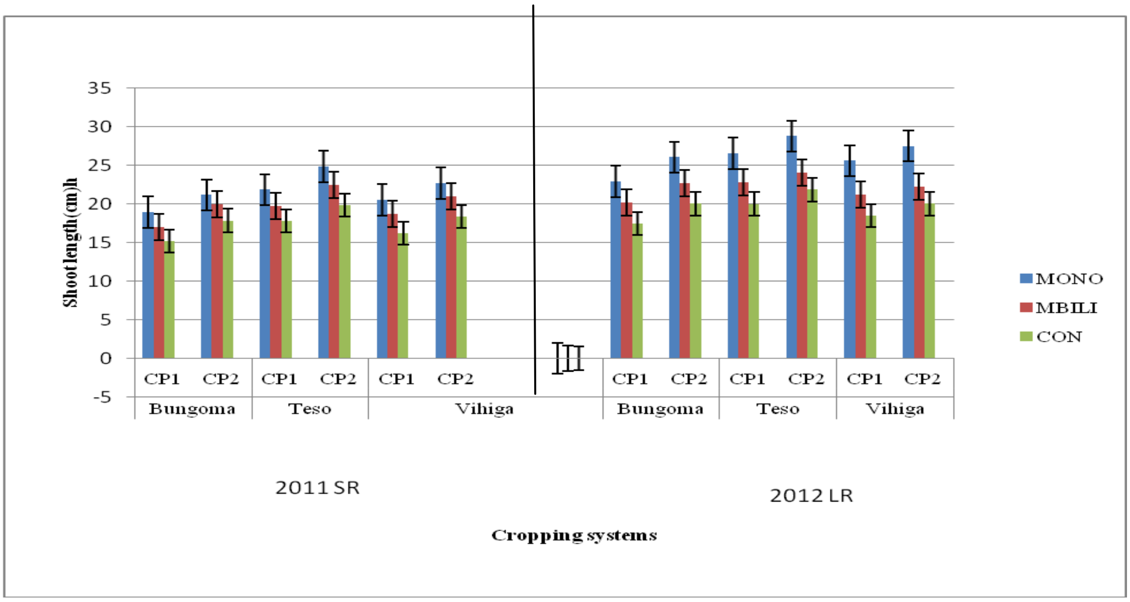


Fig.4.3: Effect of cropping systems (monocrop,MBILI.conventional) on average shoot lengths of the two-cowpea varieties grown in the three sites during short rain season (2011) and long rain season (2012). CP1;Black-eye: CP2;Ken-kunde . Error bars represents standard error of the difference of means

4.6.2 Leaf area (LA)

Cowpea leaf area (LA) were recorded for six weeks at an interval of two weeks to monitor the differences in leaf area index (LAI) hence growth rate as affected by cropping systems. There was a small difference as a result of interaction between systems and the varieties across all the sites in season one leading to a small increase in average leaf area (ALA). An average leaf area of1.18cm^2 1.2 cm^2 was recorded in Black eye grown under monocrop in Teso and the least ALA of 0.5cm^2 in Ken kunde control in Bungoma. There was a significant difference in average leaf area (ALA), in season two. The best average leaf area (1.18cm^2) was recorded in Black eye grown under monocrop in Teso in season 2 and the least ALA ($0.4cm^2$) in Ken kunde control was recorded in Bungoma in season 1 (Fig 4.4).

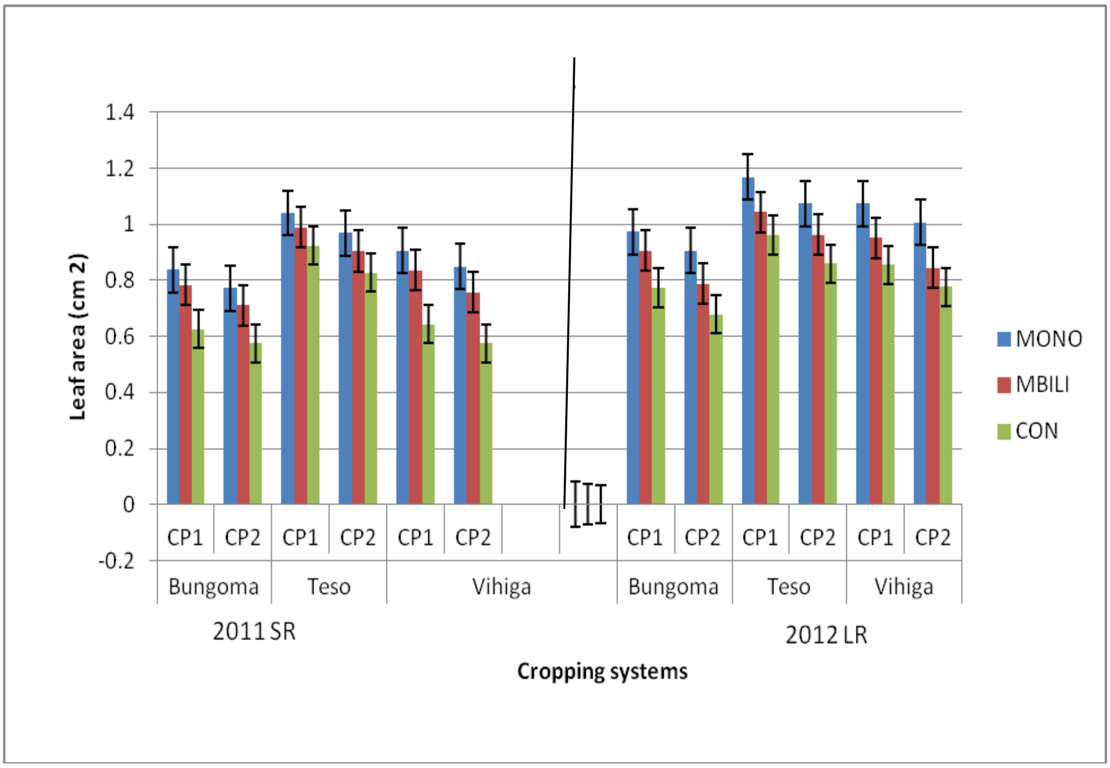


Fig.4.4: Effect of cropping systems (monocrop,MBILI and conventional) on leaf area (cm 2) of the two-cowpea varieties grown in the three sites during first rain season (2011) and second rain season (2012). CP1;Black-eye : CP2;Ken-kunde . Error bars represents standard error of the difference of means.

4.7 Changes in leaf yield (t/ha) of the two cowpea varieties grown in the three sites as a result of cropping systems during short rain season (2011) and long rain season (2012).

There was no significant difference in interaction between systems and varieties across all sites in season I. The highest leaf yield (0.9 t/ha) was recorded in Ken kunde variety grown under monocrop system in Teso. MBILI recorded (0.19 t/ha) and conventional (0.06 t/ha) at the same site. This trend was observed across all the sites.

The least leaf yield (0.1 t/ha) was recorded in Black eye variety grown in conventional system in Bungoma in season one The average leaf yields recorded across all sites was significantly different (p < 0.001). Vihiga recorded a leaf yield of 0.1 t/ha Bungoma 0.2 t/ha and Teso 0.3 t/ha. (Table 4.9).

Table 4.9: Effect of cropping systems on leaf yield (t/ha) of the two cowpea varieties grown in the three sites during short rain season (2011). CP1; Black-eye:CP2;Ken-kunde. Ns; not significant.p ≤ 0.5; the probability at or less than 5%. mono; monocrop: con; conventional

SEASON	SITE	SYSTEM	VARIETY		MEAN		
					(a)	(b)	(c)
1 (2011)			CP1	CP2			
	Vihiga	Mono	0.231	0.284	0.2575		
		MBILI	0.227	0.232	0.2295		
		Con	0.063	0.104	0.0835	0.190167	
	Bungoma	Mono	0.338	0.467	0.4025		
		MBILI	0.295	0.314	0.3045		
		Con	0.112	0.12	0.116	0.274333	
	Teso	Mono	0.852	0.937	0.8945		
		MBILI	0.104	0.198	0.151		
		Con	0.039	0.065	0.052	0.365833	0.276778
MEAN			0.2512222	0.302333	0.276778	0.276778	
Standard error of the difference (SED)				**Probability for F test (p < 0.05)**			
SED System (Sys) :Ns SED Variety (Var) :Ns SED Site (Si) :Ns SED Sys x Var : Ns SED Si x Sys x Var :Ns				System : 0.6 Variety : 0.2 Site : .001 Var x Sys : 0.4 Si x Var x Sys : 0.9			

There was a significant difference (p < 0.01) in interaction between systems and varieties across all sites in season II. The highest leaf yield (1.9 t/ha) was recorded in Ken kunde variety grown under monocrop system in Teso. MBILI recorded (1.7 t/ha) and conventional (0.9 t/ha) at the same site. This trend was observed across all the sites. The least leaf yield (0.5 t/ha) was recorded in Black eye variety grown in conventional system in Vihiga in season II. The average leaf yields recorded across all sites was significantly different ($p < 0.001$) too. Vihiga recorded a leaf yield of 0.96 t/ha Bungoma 0.99 t/ha and Teso 1.3 t/ha. (Table 4.10).

Table 4.10 Effect of cropping systems on leaf yield (t/ha) of the two cowpea varieties grown in the three sites during long rain season (2012). CP1;Black-eye :CP2;Ken-kunde . Ns; not significant.p ≤ 0.5; the probability at or less than 5%. mono; monocrop: con; conventional

SEASON	SITE	SYSTEM	VARIETY		MEAN		
					(a)	(b)	(c)
2 (2012)			CP1	CP2			
	Bungoma	Mono	0.939	1.5	1.2195		
		MBILI	0.852	1.206	1.029		
		Con	0.626	0.82	0.723	0.9905	
	Teso	Mono	1.461	1.992	1.7265		
		MBILI	1.229	1.766	1.4975		
		Con	0.852	0.918	0.885	1.36966	
	Vihiga	Mono	1.157	1.339	1.248		
		MBILI	0.918	1.077	0.9975		
		Con	0.534	0.786	0.66	0.9685	1.109556
MEAN			0.952	1.267111	1.109556	1.109556	

Standard error of the difference(SED)	**Probability for F test (p < 0.05)**
SED System (Sys) :Ns	System (sys) :0.01
SED Variety (Var) :Ns	Variety (var) :0.08
SED Site (Si) :Ns	Site (si) : 0.001
SED Sys x Var : Ns	Var x Sys :0.01
SED Si x Sys x Var :Ns	Si x Var x Sys :0.5

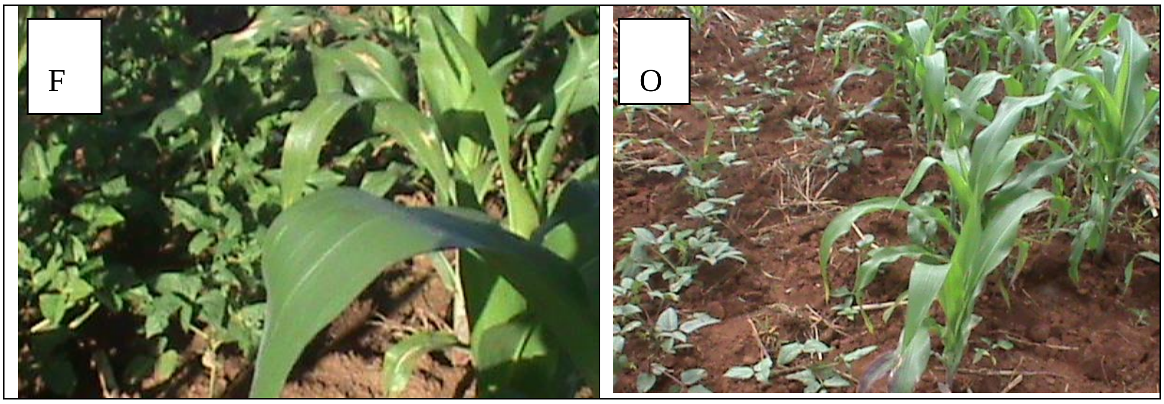


Plate 6: Cowpea varieties grown with different manure in MBILI system in Bungoma.F:cowpea grown with fortified manure,O:cowpea grown with ordinary manure

4.9 Effect of cropping systems and manure quality on financial benefit of growing cowpea:

4.9.1 Benefit - Cost analysis ha^{-1}

The net benefit and benefit - cost ratio (BCR) were high in season two than in season one (Table 4.11). The net benefit increased when the ordinary manure was fortified in season II. The benefit - cost ratio in season one ranged between -0.28 to 3.4 while that for season two ranged between -0.3 to 4.1. The MBILI cropping system had a higher net benefit both in season one and two respectively (Table 4.11). Both cowpea varieties had a higher financial benefit and benefit - cost ratio when grown with fortified manure under MBILI system. Both cowpea varieties however performed poorly under conventional systems but well under monocrop system but with a low BCR in both systems (Table 4.11).

Table 4.11: Effect of manure quality and cropping systems on CBR and net Benefit per ha. of maize – cowpea. TVC:Total-variable-cost:NB:Net-benefit:BCR: Benefit-Cost-Ratio.Var.:variety.con: conventional, mono: monocrop

SEASON I							EASON II					
NUTRIENT	SYSTEMS	VAR.	TVC (Ksh)	NB(Ksh)	BCR		NUTRIENT	SYSTEMS	VAR.	TVC (Ksh)	NB (Ksh)	BCR
CONTROL	MONO	CP1	5350	-1534	-0.28673		CONTROL	MONO	CP1	19500	-5964	-0.30585
		CP2	5350	-202	-0.03776				CP2	19500	-960	-0.04923
	CON	M2CP1	9850	2849	0.289239			CON	M2CP1	24000	-551	-0.02296
		M2CP2	9850	3317	0.336751				M2CP2	24000	-2855	-0.11896
		M1CP1	9850	5873	0.596244				M1CP1	24000	-2310	-0.09625
		M1CP2	9850	6341	0.643756				M1CP2	24000	-1518	-0.06325
	MBILI	M2CP1	9850	7839.5	0.795888			MBILI	M2CP1	24000	1682	0.070083
		M2CP2	9850	8631.5	0.876294				M2CP2	24000	3986	0.166083
		M1CP1	9850	11242	1.14132				M1CP1	24000	11798	0.491583
		M1CP2	9850	12034	1.221726				M1CP2	24000	13742	0.572583
MANURED	MONO	CP1	5350	5450	1.018692		MANURED	CON	M2CP1	24000	47258	1.969083
		CP2	5350	7862	1.469533				M2CP2	24000	51650	2.152083
		M2CP1	9850	13825	1.403553				M1CP1	24000	60456	2.519
		M2CP2	9850	15913	1.615533				M1CP2	24000	64848	2.702
		M1CP1	9850	23527	2.388528			MONO	CP2	24000	69420	2.8925
		M1CP2	9850	25615	2.600508			MBILI	M2CP1	24000	69573	2.898875
	CON	M2CP1	9850	26695	2.710152			MONO	CP1	19500	58512	3.000615
		M2CP2	9850	27955	2.838071			MBILI	M1CP2	24000	75657	3.152375
	MBILI	M1CP1	9850	31168	3.164264				M1CP1	24000	93198	3.88325
		M1CP2	9850	32428	3.292183				M1CP2	24000	99282	4.13675

CHAPTER FIVE

DISCUSSION

5.1 Factors affecting technology adoption among small-scale farmers

The survey characterized the respondents (Table 4.3), identified promising existing technologies (Table 4.1) and adoption rates (Table 4.2). Many technologies were identified to be in existence but the rate of adoption was low thus the need to promote them. The results revealed that some of the factors that are important in influencing adoption of technology and its intensity among small scale farmers include. (1) Site (county) where the farmer resides, (2) know-how on value addition, (3) knowledge on the technology, (4) availability of inputs, (5) age of household head (6) membership of an FA. Some of these variables mirrored the findings from Mazuze (2005), who observed that adoption of technologies among sweet potato farmers in western Kenya is affected by the district where the respondent resides, effectiveness of extension and availability of vines to farmers. Mazuze (2005) further observed that to spur adoption of available technologies, it is important to identify market opportunities for processed products and link farmers to potential processors and market outlets.

According to the results, being in Bungoma County decreased the possibility of adopting technology than being in Vihiga and Teso. A farmer in Teso was most likely to adopt a technology compared to a farmer in Bungoma. This could have been due to several underlying factors, which included the fact that farming was more commercialized in Teso and Vihiga counties than in Bungoma County and the yields of the common varieties of crops grown in Bungoma were comparable to the yields of the new crop varieties being introduced. A study by Kaguongo *et al.,* (2010) among sweet potato farmers on orange fleshed potato (OFP) processing technology adoption showed that the yield of the new potato variety and ability of the farmers to access market for the potato affected its adoption. More importantly, the short time of programme implementation may not have had sufficient effect on farmers' preferences that may not have been willing to adopt the less familiar technologies in Bungoma County a similar observation having been made by Jean-Philippe (2011). Strengthening FAs administrative structures and training their leaders on management skills can be a sure way of building their capacity as extension agents of their members farmers who will be sensitised about benefits of integrating the existing technologies in farming. The same site specific reasons affecting adoption are suspected to affect intensity of adoption Mazuze (2005.

More farmers in FAs had adopted the technologies than those who were not. This is according to the expectation of the programme implementers and researchers. Although the programme was implemented for about3 years, it means that farmers participating in the programme had a higher probability of adopting the technologies that were being promoted. This result offers justification for impact analysis i.e. researchers can conduct a more robust econometric analysis to evaluate intensity and impact of adoption using differences in differences (DD) as suggested by Kaguongo *et al*., (2011). However, results of the study indicated that being in an FA did not significantly influence the intensity of adoption. This means that once a programme influenced farmers to adopt new crop varieties for instance, other non-programme factors were more important in determining the proportion of land allocated to such new crops (Kristjanson,1987).

Farmers who had the know-how on legume processing techniques were more likely to adopt the legumes (soya beans and cowpea) that were being promoted than those who did not have the know-how. The legumes that were being promoted were known to fetch lower prices when sold at farm gates and hence farmers were more likely to prefer further value addition (Rao, 2000). This means that since dissemination of value addition techniques was included in intervention programmes, the adoption rate is likely to increase; an observation made by Doss (2003) during his study on factors affecting technology management at farm level. Results of the study also suggest that having know-how of value addition had a significant positive effect on intensity of adoption.

The results too suggest that farmers who had the knowledge about the existing technologies were more likely to adopt them than those who did not know (Table 4.3). This means any programme that includes effective training on advantages and disadvantages of a technology enhance its adoption (Doss, 2003).

The results suggest negative impact of constraint of access to farm inputs i.e. farmers who have limitations in accessing the fertilisers and seeds being promoted are less likely to adopt and use them. This is in agreement with a study on factors affecting fertilizer use among small scale farmers in western Kenya by Kipkoech *et al*., (2010) which showed that access to inputs increased their rate of use by farmers. The results means that an intervention programme that includes training farmers on how to bulk and preserve seeds as well source economical soil fertility improvement techniques is more likely to increase their availability, use and intensity of adoption.

The age of the household head had a negative sign as expected. According to the results, if age of the household head increases by one year, the odds in favour of not adopting increases.

The main reasons given for older people being less likely to adopt new technologies is that they are said to be less receptive to new ideas and are less willing to take risks. This means there may be a need to review methods of technology dissemination used in the intervention programme to ensure that they are attractive to both young and old farmers .A study by Kaguongo *et al.,* (2010) identified age, level of education and knowledge on value addition as some factors that were affecting technology uptake among small-scale farmers involved in sweet potato production, concurring with the above factors. The community action research (CARP) approach taken by the project was intended to involve farmers in umbrella associations (an extension provider) during all the project phases thus increase their sense of technology ownership, adoption and adaptation. A study by Cuellor *et al*.,(2006) and Jean-Philippe (2011) concurred that effective extension service provision improves rate of technology adoption among farmers The rate of disseminating these technologies among farmers can therefore be more effective when umbrella associations are used to reach the target groups.

5.2 Changes in soil chemical characteristics as a result of manure application

The magnitudes and patterns of changes in soil in (0-15 cm depth) because of manure addition recorded across all sites and seasons (Table 4.5 and 4.6). The low soil acidity at the beginning of the first season may have been associated with high concentration of H^{+} and AL^{+3} cations, which occur when bases are leached after heavy rainfall.

Growing crops also extract large quantities of K, Ca and Mg and if such nutrients are not replenished, soils become acidic. Prolonged use of fertilizers with ammonium forms of nitrogen is also known to acidify soils through release of H^+ during conversion of ammonium to nitrates as observed by Okalebo *et al.,* (1994). The use fortified manure improved soil condition increasing pH, total nitrogen and available phosphorus.

Organic manures are known to release substances that form chelates with Fe and Al ions in the soil solution, preventing precipitation of phosphates and reduce Fe and Al toxicity. Such substances also compete with P for sorption sites and solubilise P from insoluble Ca, Fe and Al phosphates then become available to plants (Agbede *et al.,* 2008). Organic matters also add carbon to the soil and provide substrate for microbial growth and activities. Enhanced decomposition results in nutrient recycling and availability of N and P for root development and vegetative growth.

The use of fortified manure increased the soil pH across all sites (Table 4.2). The increased pH could have resulted from availability of calcium, which dissociated from Calcium Ammonium Nitrate (CAN) fertilizer thereby replacing AL^{+3} and Fe^{+3} on the cation exchange sites a similar observation made by Okalebo *et al.,* (2002). From Table 4.2, there is an indication that soil pH influenced the N, P and C in soil as seen across the three sites. Bungoma site with the highest pH had a higher level of N and P compared to Teso and Vihiga sites. The soil pH influences the rate of plant nutrient release during the weathering process, the solubility of soil nutrients and amount of nutrient ions stored on the cat ion exchange sites comparing to a similar observation by Agbede *et al.,* (2008). Less acidic soils are known to favor microbial activity and organic matter decomposition, which contribute to increased release of soil nutrients and their subsequent mineralization to forms available to plants. The soil texture (sandy loam) is also thought to have enhanced the capacity of soil to store nutrients thus an increased pH (Lekasi *et al.,* 2001).

5.3 Effect of manure fortification and variety on the cowpea growth parameters

The difference in shoot length and leaf area between the two cowpea varieties realized across the two seasons could have been because of increased nutrients supplied by the fortified manure and its uptake because of available moisture. The shorter shoots and small leaf area in season one could be attributed to low N and P in the soil. This might not have improved with addition of low nutrient non fortified) organic manure (Fig.4.1 and 4.2). Low level of N in the soil affects cell division and elongation in the meristematic tissues. An increase in leaf area and plant shoot elongation occurred when the crop was grown with fortified manure (Fig.4.1 and 4.2). The nutrient rich manure boosted the rate of growth and subsequent shoot lenght and leaf diameter. The increase in plant shoot elongation and leaf area with an increased nutrient supply resulted in an increase in cell division and elongation in the meristematic tissues.

Larger leaves are known to increase surface area for photosynthesis and amount of biomass a plant produces (Balemi, 2009). This could be attributed to the fact that manure releases nutrients gradually through the process of mineralization (Agbede *et al.,* 2008) maintaining optimal soil level over a long period. The main function of organic matter in the soil is release of nutrients and increase in organic materials. The significance of organic matter in soil is determined by its rate of decomposition and mineralization to release nutrients. The slower the process the more additive it will be to the soil. Other than improving the soil chemical properties, organic matter also improves the soil physical properties allowing an extensive root growth and establishment. This enhances absorption of nutrients and water, necessary for crop growth and establishment resulting in longer plant shoots with broader leaves. Ayoola *et al.*, (2009) too reported that fortification of organic manure led to an increase in maize growth and yield response. The well distributed rainfall in season 2 (Appendix 9, 10 and 11) might have contributed to high nutrient uptake for plant growth. This was also observed by Ondieki (2011) that an increase in phosphate uptake increased plant height, leaf area and number of leaves / plant in African nightshade. The difference in height and leaf area between the varieties may have been due to genetic makeup of individual plant. Ken kunde, which is an improved variety with a hybrid vigor, had an ability to convert nutrients more efficiently to cellular materials for cell division and elongation compared to black eye variety. The higher rate of growth of Ken kunde grown with fortified manure over that grown with ordinary manure and the control is in agreement with Abukutsa (2011) that an interaction between the genetic makeup and soil fertility level influences crop growth and development.

5.4 Effect of manure fortification on fresh and dry leaf weght

5.4.1 Fresh and dry leaf weght

The fortified organic manure used in the second season had a significant interaction ($p < 0.01$) with both cowpea varieties resulting in a positive increase in leaf yield across all the sites (Table 4.8). The results indicated that Ken kunde variety had better leaf yield the highest bieng 2.3 tonnes (Teso) above the average farmers value of 200kg-500 kg/ha compared to Black eye the least being 0.1 tonnes (Vihiga). These results differed significantly with that obtained (1.1 tonnes) by Abukutsa (2011) when she used 5 t ha of fortified manure (N=2.13 % and P=3.38 %) to grow cowpeas in Kakamega.The difference in yields could have resulted from the quality of manure used and the seasonal changes in the study sites.The positive correlation (Ndungu,2003) between the available P, total N and leaf yield could be an indication that application of fortified manure increases yields.The well distributed rainfall in season 2 (Appendix 14 and 15) could have enabled the plants to increase their N and P uptake. There was a highly significant difference ($p < 0.001$) between yields of the cowpea varieties across sites and no significant difference between the varieties within seasons.This suggested that both varieties had a potential to perform well under good soil conditions. Both cowpea varieties grown with fortified manure gave high leaf yield (Table 4.8),conquering with results obtained by Abukutsa (2011) with different cowpea genotypes.Yields on control plots declined suggesting decline in soil fertility resulting from continous cropping. The leaf yield paterns in Vihiga may have been lower due to low soil pH (Table 4.5 and 4.6) which promotes P fixation and high rainfall (Appendix 13) in both seasons. Cowpea is known to be susceptible to high soil moisture.P too is known to be a limiting factor in legume performance because it promotes root expansion development and its capacity to absorb nutrients. Legumes too require starter nitrogen in the initial establishment phase before starting the nitrogen fixation process (Okalebo *et al.,* 2002). Fortified manure had an ability to supply high starter N to enhance ability of the plants to fix N for shoot development and establishment.It also increased the pH of the soil which was necessary for release of previosly fixed P for root development. This in turn led to increased vegetative growth which consequently favoured carbohydrate build up resulting into higher leaf yield. The higher yields obtained from fortified organic manure treated plots is a clear indication that intergration of organic and inorganic nutrient inputs increaseas fertilizer use efficiency (FUE) and provides more balanced nutrients. Similar studies by (Balasubramanian *et al.*,1980; Suge *et al*., 2011) indicate that intergration of different soil nutrient sources lead to synergy and a balance between nutrient released and crop requirements thus higher fertilizer use efficiency and higher yields.

The difference in biomass production from the two varieties grown could have been a difference in photosynthetic efficiency. The ordinary manure promoted little growth that included small leaf area.This reduced photosynthesis efficiency and the total plant biomass.Maximum biomass production was realised when fortified manure was used meaning that it supported both lateral and vertical growth and when the tender shoots were harvested a higher weight was realised. The cowpea variety grown also affected the amount of biomass produced.The Black eye variety is known to produce broader but fewer leaves compared to the Kenkunde (Plate 5).With more leaves plants increase photosynthesis leading to total biomass production.

5.5 Interaction between manure, cropping systems and variety on leaf yield

There was a small difference in yields of both varieties grown with the ordinary manure and the control under all the cropping systems.The amount of N and P released by ordinary manure used in season (Table 4.4), one did not inflence the perfomance of both varieties under all the systems. This was in agreement with a study done Agbede *et al*., (2008) when he observed that maize grown by fortified farm yard manure performed better than that grown with ordinary manure under three cropping systems. On the other hand, there was a significant difference of $p < 0.005$ (Table 4.8) in interaction between systems, nutrient and varieties across all sites in season two resulting in high leaf yield. Results showed that leaf yield of Ken kunde grown with fortified manure in monocrop system was significantly higher ($p < 0.001$) across all sites. Though the yield obtained from monocrop system was significantly higher, the system did not take into account the advantages associated with intercrops when a farm holding is small. The intercrop systems and more specifically the MBILI system were therefore more suitable to the smallholder farmers of western Kenya. Yields obtained from all sites indicated that Ken kunde variety grown with fortified manure under MBILI system had better leaf yieid (1.7 t/ha) above the average farmers value of 200kg-500 kg/ha, compared to Black eye variety (1.2 t/ha) under the same system.Either of the two varieties grown in MBILI system perfomed better than that grown in conventional (0.6 t/ha) system (Table 4.10). The results of this study concured with that of Ruto, (2008) that crops grown under MBILI system had an improved ability to absorb and utilise nutrients thus best crop growth characteristics and yield parameters. Another study conducted by Tungani *et al.* (2002) compared conventional and MBILI intercrops of maize and beans; green gram and groundnut with and without 150 kg DAP per ha. Included, as treatments were maize and legume monocrop to compare the two-intercrop systems and calculate the overall advantages of intercropping over monocropping. Results of that study indicated that maize grown under the MBILI row arrangement performed slightly better than conventional intercropping. In addition, combining MBILI and DAP fertilizer increased the profits by 44%.The MBILI spartial arrangement improves light penetration,reduces attacks from pests and pathogens and increases root penetration.This leads to high rates of nutrient absorption and photosynthesis,which increases vegetative growth consequently favouring carbohydrate build up resulting into higher leaf yield compared to conventional intercrop.

Ken kunde variety showed a more superior perfomance under favourable soil conditions and agronomic practices compared to Black eye variety. Its vigorous growth and higher yield pointed towards the hybrid vigour which is a characteristic of certified seeds. The increased soil pH due to addition of fortified manure contributed to the release of previosly fixed P, a condition that characterises the acidic soils of western Kenya (Anjejo, 1996). Other than P,other basic cations that enhance plant growth may have also been released into the soil. Application of fortified manure on Kenkunde under the spartial MBILI arrangement combined with its hybrid vigour increasing its growth and established, phosynthesis and was able to produce a higher biomass as opposed to the local Black eye variety (Abukutsa, 2011).

5.6 Effect of manure quality and cropping systems on financial benefit of growing cowpea

5.6.1 Financial benefit and benefit - cost analysis

The cost- benefit analysis obtained indicated that there was a higher financial benefit associated with the use of fortified manure in MBILI system. Use of ordinary manure in season one did not have any significant increase in leaf yield within the different cropping systems (Table 4.11). Even though production costs were lower in season one,the financial benefit and BCR (2.0 to 3.0) were low because of lower yields attained (Table 4.11). Finacial benefit and BCR (3.0 to 4.1) in season 2 were high due to an increase in leaf yields obtained (Table 4.11). Fortification of manure increased the costs of inputs and labour but this was neutralised by the benefits that resulted from increseased yields. Farmers usually prefer BCR of more than 2.0 (Opala *et al*., 2012), and from the above results,use of fortified manure in MBILI intercrop was therefore more beneficial because the farmers benefited both from the cowpea and maize.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions.

The use of community action research brought a complete shift from an outreach to an engagement approach to research.A forum was created in which all stake-holders shared the hard science and soft learning skills during the entire research period. This coupled with capacity building through on field trainings,the level of problem identification and management using various technologies among the target farmer groups increased

Fortification of organic manure improved the N and P levels in the soil, that enhanced growth attributes and yield parameters of cowpea. This resulted in a significantly ($p < 0.001$) higher cowpea leaf yields of 2.3 t / ha. This was above the average farmers yield of 0.2 t / ha. Use of non-fortified manure did not influence growth and yield parameters positively and had no sinificant difference with yield and growth parameters recorded when no manure was applied.

Fortified manure applied to cowpea under MBILI system positively improved the soil condition and resulted in best growth characteristic and yield parameters influencing the financial benefit. The high BCR in season two make manure fortification and MBILI system easily adoptable because they had between 300 % - 400 % financial benefit over added costs from the control. MBILI system on the other had is appropriate to small holder farmers. The choice of cowpea variety grown will depend on farmers and consumers choice and preference and associated BCR and financial benefit

6.2 Recommendations

6.2.1 Recommendation for practical use

1. Use of community action and experiential learning approach to research is an effective tool of creating an interactive learning platform among stakeholder during a research. The approach should be used because it increases rate of information dissemination, adoption and adaptation. There is need to strengthen capacity building among the farmers in order to train them on problem identification and management skills. This should be aimed at empowering them to critically understand the structures and impacts of the technologies on promotion. This will work along way in improving their adoption and adaptation rates as well as their ability to disseminate the skills acquired.

2. Preparation of fortified manure should be managed and commercialized by trained contact farmers and community based farmer organizations. This will standardize its quality and make it available and accessible to farmers at subsidized prices.Fortification provides an affordable and more cost effective alternative to the use of large quantities of low value organic manures. As much as 1 tonne of farmyard manure can be fortified with as little as 100 kg CAN and 50 kg TSP to meet application requirement as recommended by FURP (1994). Rate of fortified manure application should be between 2 t/ha - 5 t/ha depending on the soil condition. Application of side dressing N fertilizer in two equal splits of 20 kg N/ha is necessary to enhance the effect of the manure and biological nitrogen fixation. This will restore soil fertility; improve crop yield, income and food security.

3. MBILI cropping system is a suitable system for small-holder farmers because it results in a high BCR and financial benefit. Most farmers recommended that MBILI layout should be improved in such a way that one row of a cereal is staggered with two rows of a legume to reduce on the labor associated with the conventional MBILI system.

6.2.2 Recommendations for further studies

1.There is need to breed cowpea varieties that are early maturing and can tolerate high rainfall amounts like that received in Vihiga.

2. Ken kunde was high yielding but famers across all the three zones preffered the black eye because it had an appealing taste and texture.Quality of Ken kunde should be improved to make it more appealing to farmers.

3. Although studying compartibility of different cowpea varieties in maize intercropps was not an objective of this study,it was observed that Ken kunde had a vigorous growth tendency and often was aggressive and choked maize reducing its yield. More compartible and suitable varieties need to be identified for intercrops.

4. Need to breed a variety that combines advantages exhibited by both the black-eye and the Ken-kunde variety.

5. There is need to carry out further research and assessment on effectiveness of community action research on rate of technology adoption and adaptation.

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APPENDICES

Appendix 1: Field Plans

BLOCK 1

	Treatment 1				**Treatment 2**			
1	M1	CP2	M2	CP1	CP1	M1	CP2	M2
2	M1 CP1	M2 CP2	M1 CP2	M2 CP1	M2 CP2	M2 CP1	M1 CP2	M1 CP1
3	M2 CP1	M1 CP2	M2 CP2	M1 CP1	M1 CP1	M2 CP1	M2 CP2	M1 CP2

BLOCK 2

	Treatment 2				**Treatment 1**			
1	M1	CP2	M2	CP1	CP2	M2	CP1	M1
2	M2C P1	M2 CP2	M1 CP1	M1 CP2	M2 CP2	M2 CP1	M1 CP2	M1 CP1
3	M2C P1	M1 CP2	M2 CP2	M1 CP1	M1 CP2	M2 CP1	M1 CP1	M2 CP2

BLOCK 3

	Treatment 1				**Treatment 2**			
1	M2	CP1	M1	CP2	CP2	M2	CP1	M2
2	M1 CP1	M2 CP2	M2 CP1	M1 CP2	M1 CP1	M2 CP2	M1 CP2	M2 CP1
3	M2 CP2	M1 CP1	M1 CP2	M2 CP1	M1 CP1	M2 CP2	M1 CP2	M2 CP2

Legend: SEASON I
Nutrient levels: Treatment 1:Farm-yard manure(4 t/ha) Treatment 2:No farm yard manure
Cropping systems:1; Mono crop **,**2;Conventional cropping **,**3;MBILI cropping
Varieties:M1;Farmer's maize ,M2; IR maize, CP1;Farmer's cowpea ,CP2;Ken-Kunde
SEASON II: Nutrient levels: Treatment 1: Fortified Farmyard manure (2.5 t/ha)**,** Treatment 2: No farmyard manure

Design:
Split-Split plot in RCBD with 3 replicates

Spacing:

Block	1m
Plot	0.5m

Appendix 2a: Analysis of variance table LRS 2011

Variate;Haulm t/ha						
Source of variation	**d.f.**	**(m.v.)**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2		0.22524	0.11262	6.61	
SITE	2		0.38477	0.19239	11.29	<.001
SYSTEM	2		0.03161	0.0158	0.93	0.27
Nutrient	1		0.0408	0.0408	2.39	0.007
SITE.SYSTEM	4		0.07843	0.01961	1.15	0.015
SITE. Nutrient	2		0.02741	0.0137	0.8	0.001
SYSTEM. Nutrient	2		0.07356	0.03678	2.16	0.649
SITE.SYSTEM.Nutrient	4		0.14568	0.03642	2.14	0.413
Residual	**163**		**2.77865**	**0.01705**		
Total	**182**		**3.69485**			

Appendix 2b: Analysis of variance table LRS 2012

Variate;Haulm t/ha					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2	0.6726	0.3363	1.58	
SITE	2	6.8142	3.4071	15.97	<.001
SYSTEM	2	4.9069	2.4535	11.5	0.08
Nutrition	1	184.908	184.908	866.88	0.004
SITE.SYSTEM	4	1.0318	0.258	1.21	0.556
SITE.Nutrition	2	0.0721	0.036	0.17	<.001
SYSTEM. Nutrition	2	2.7868	1.3934	6.53	0.001
SITE.SYSTEM.Nutrition	4	0.6544	0.1636	0.77	0.519
Residual	**160**	**34.1282**	**0.2133**		
Total	**179**	**190.826**			

Appendix 3: Effect of manure application on shoot length (cm) SRS 2011

SEASON	SITE	VAR	NUTRIENT		MEAN		
			Control	Manured	(a)	(b)	
II (2012)	BUNGOMA	CP1	0.2	0.271	0.2355	0.2757	
		CP2	0.24	0.392	0.1972		
	TESO	CP1	0.248	0.322	0.285		
		CP2	0.28	0.41	0.345	0.2817	
		CP1	0.215	0.222	0.2185		
	VIHIGA	CP2	0.25	0.41	0.33	0.165	
MEAN			0.23883	0.33783	0.26853	0.2408	
	Site(Si)	VAR (Va)	Nut (Nu)	Si xVa	Si xNu	VaxNu	SixVaxN
S.E	0.0863	0.0292	0.0352	0.0742	0.0829	0.0457	0.0971
S.E.D	0.122	0.0413	0.0497	0.105	0.1173	0.0646	0.1374
F-prob	0.001	0.163	< .001	0.537	0.001	0.709	0.267
% C.V	3.5						

Appendix 4: Effect of manure application on shoot length (cm) LRS 2012

SEASON	SITE	VAR	NUT/ YIELD		MEAN		
			Control	Manured	(a)	(b)	
II (2012)	BUNGOMA	CP1	0.22	0.44	0.33	0.37	
		CP2	0.24	0.58	0.41		
	TESO	CP1	0.24	0.58	0.41		
		CP2	0.3	0.6	0.45	0.43	
	VIHIGA	CP1	0.21	0.4	0.305		
		CP2	0.28	0.48	0.38	0.3425	
MEAN			0.24833	0.51333	0.38083	0.38083	
	Site(Si)	VAR (Va)	Nut (Nu)	Si xVa	Si xNu	VaxNu	SixVaxN
S.E	0.0963	0.0292	0.0452	0.0742	0.0829	0.0457	0.0871
S.E.D	0.132	0.0413	0.0597	0.105	0.1273	0.0646	0.1474
F-prob	0.001	0.154	<.001	0.156	0.001	0.654	0.422
% C.V	9						

Appendix 5: Effect of manure application on leaf area (cm^2) SRS 2011

SEASON	SITE	VAR	NUT/ YIELD		MEAN		
			Control	Manured	(a)	(b)	
		CP1	0.7596	1.099	0.9293	0.8799	
	BUNGOMA	CP2	0.653	1.008	0.8305		
		CP1	0.7213	1.179	0.95015		
	TESO	CP2	0.659	1.038	0.8485	0.8993	
		CP1	0.7393	1.017	0.87815		
II (2012)	VIHIGA	CP2	0.6486	0.857	0.7528	0.8154	
MEAN			0.6968	1.033	0.8649	0.86487	
	Site(Si)	VAR (Va)	Nut (Nu)	Si xVa	Si xNu	VaxNu	SixVaxN
S.E	0.0863	0.0292	0.0352	0.0742	0.0829	0.0457	0.0971
S.E.D	0.122	0.0413	0.0497	0.105	0.1173	0.0646	0.1374
F-prob	0.001	0.001	0.004	0.156	0.001	0.005	0.322
% C.V	5						

Appendix 6: Effect of manure application on leaf area (cm^2) SRS 2012

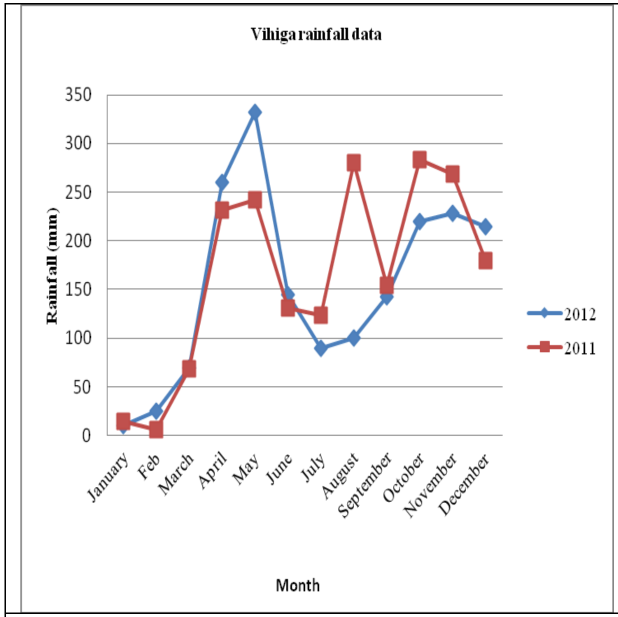
SEASON	SITE	VAR	NUT/ YIELD		MEAN		
			Control	Manured	(a)	(b)	
		CP1	0.771	1.232	1.0015		
	BUNGOMA	CP2	0.7046	1.121	0.9128	0.95715	
		CP1	0.896	1.378	1.137		
	TESO	CP2	0.838	1.256	1.047	1.092	
		CP1	0.7443	1.156	0.95015		
II (2012)	VIHIGA	CP2	0.6853	1.082	0.88365	0.9169	
MEAN			0.7732	1.20417	0.98868	0.98868	
	Site(Si)	VAR(Va)	Nut (Nu)	Si xVa	Si xNu	VaxNu	SixVaxNu
S.E	0.0963	0.0192	0.0342	0.0752	0.0828	0.0467	0.0871
S.E.D	0.132	0.0433	0.0487	0.205	0.1273	0.0656	0.1274
F-prob	0.001	0.123	0.001	0.146	0.001	0.004	0.232
% C.V	8.9						

Appendix 7: Effect of cropping systems and manure regimes on BCR and Net Benefit 2011 SRS:

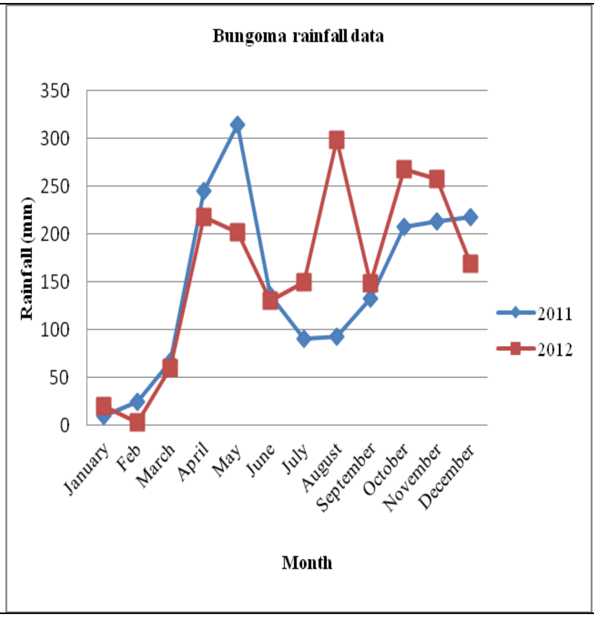
TREATMENTS	CP1	CP2	M1CP1	M1CP2	M2CP1	M2CP2	M1CP1	M1CP2	M2CP1	M2CP2	CP1	CP2	M1CP1	M1CP2	M2CP1	M2CP2	M1CP1	M1CP2	M2CP1
Average yield of cowpea (kgs/ha)	376	515	283	337	283	337	177	241	177	241	2167	2470	1600	1769	1600	1769	1107	1229	1107
Average adjusted yield of cowpea (kgs/ha)	338.4	463.5	254.7	303.3	72.7	92.7	159.3	216.9	159.3	216.9	1950.3	2223	1440	1592.1	1440	1592.1	996.3	1106.1	996.3
Yield*Price for cowpea (ksh 40/kg)	13536	18540	10188	12132	2916	3708	6372	8676	6372	8676	78012	88920	57600	63684	57600	63684	39852	44244	39852
Average yield of maize (kgs/ha)	0	0	813	813	596	596	613	613	469	469	0	0	1892	1892	1142	1142	1416	1416	997
Average adjusted yield of maize (kgs/ha)	0	0	731.7	731.7	536.4	536.4	551.7	551.7	422.1	422.1	0	0	1702.8	1702.8	1027.8	1027.8	1274.4	1274.4	897.3
Yields*price of maize (Ksh 35/kg)	0	0	25609.5	25609.5	18774	18774	19309.5	19309.5	14773.5	14773.5	0	0	59598	59598	35973	35973	44604	44604	31405.5
Gross field Benefits for maize and cowpea(Ksh/ha)	13536	18540	35797.5	37741.5	21690	22482	25681.5	27985.5	21145.5	23449.5	78012	88920	117198	123282	93573	99657	84456	88848	71257.5
Costs that vary																			
Cost of maize seed (150/kg)	0	0	1500	1500	1500	1500	1500	1500	1500	1500	0	0	1500	1500	1500	1500	1500	1500	1500
Cost of biofix	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Cost of cowpea seed (150/kg)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Cost of fertilizer 59 kg TSP	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310
Cost of fertilizer 144 kg CAN	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640
Fertilizer and seed transport	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Planting	1000	1000	2000	2000	2000	2000	2000	2000	2000	2000	1000	1000	2000	2000	2000	2000	2000	2000	2000
Weeding	2000	2000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	4000	4000	4000	4000	4000	4000	4000
Total Cost that varies (TCV)	19500	19500	24000	24000	24000	24000	24000	24000	24000	24000	19500	19500	24000	24000	24000	24000	24000	24000	24000
Net benefit (Ksh/ha)(GFB-TCV)	-5964	-960	11797.5	13741.5	-2310	-1518	1681.5	3985.5	-2854.5	-550.5	58512	69420	93198	99282	69573	75657	60456	64848	47257.5

Appendix 8: Effect of cropping systems and manure regimes on BCR and Net Benefit 2012 LRS:

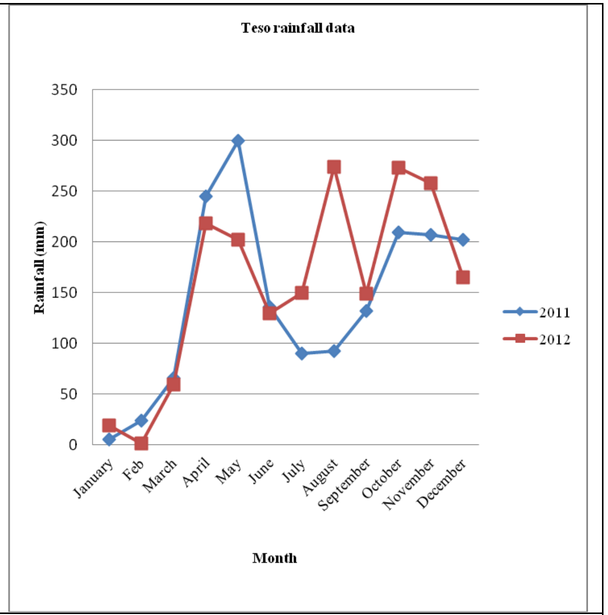
TREATMENTS	CP1	CP2	M1CP1	M1CP2	M2CP1	M2CP2	M1CP1	M1CP2	M2CP1	M2CP2	CP1	CP2	M1CP1	M1CP2	M2CP1	M2CP2	M1CP1	M1CP2	M2CP1
Average yield of cowpea (kgs/ha)	376	515	283	337	283	337	177	241	177	241	2167	2470	1600	1769	1600	1769	1107	1229	1107
Average adjusted yield of cowpea (kgs/ha)	338.4	463.5	254.7	303.3	72.7	92.7	159.3	216.9	159.3	216.9	1950.3	2223	1440	1592.1	1440	1592.1	996.3	1106.1	996.3
Yield*Price for cowpea (ksh 40/kg)	13536	18540	10188	12132	2916	3708	6372	8676	6372	8676	78012	88920	57600	63684	57600	63684	39852	44244	39852
Average yield of maize (kgs/ha)	0	0	813	813	596	596	613	613	469	469	0	0	1892	1892	1142	1142	1416	1416	997
Average adjusted yield of maize (kgs/ha)	0	0	731.7	731.7	536.4	536.4	551.7	551.7	422.1	422.1	0	0	1702.8	1702.8	1027.8	1027.8	1274.4	1274.4	897.3
Yields*price of maize (Ksh 35/kg)	0	0	25609.5	25609.5	18774	18774	19309.5	19309.5	14773.5	14773.5	0	0	59598	59598	35973	35973	44604	44604	31405.5
Gross field Benefits for maize and cowpea(Ksh/ha)	13536	18540	35797.5	37741.5	21690	22482	25681.5	27985.5	21145.5	23449.5	78012	88920	117198	123282	93573	99657	84456	88848	71257.5
Costs that vary																			
Cost of maize seed (150/kg)	0	0	1500	1500	1500	1500	1500	1500	1500	1500	0	0	1500	1500	1500	1500	1500	1500	1500
Cost of biofix	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Cost of cowpea seed (150/kg)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Cost of fertilizer 59 kg TSP	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310	5310
Cost of fertilizer 144 kg CAN	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640	8640
Fertilizer and seed transport	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Planting	1000	1000	2000	2000	2000	2000	2000	2000	2000	2000	1000	1000	2000	2000	2000	2000	2000	2000	2000
Weeding	2000	2000	4000	4000	4000	4000	4000	4000	4000	4000	2000	2000	4000	4000	4000	4000	4000	4000	4000
Total Cost that varies (TCV)	19500	19500	24000	24000	24000	24000	24000	24000	24000	24000	19500	19500	24000	24000	24000	24000	24000	24000	24000
Net benefit (Ksh/ha)(GFB-TCV)	-5964	-960	11797.5	13741.5	-2310	-1518	1681.5	3985.5	-2854.5	-550.5	58512	69420	93198	99282	69573	75657	60456	64848	47257.5



Appendix9: Rainfall data 2011 SR and 2012 LR Vihiga



Appendix 10: Rainfall data 2011 SR and 2012 LR Bungoma



Appendix 11: Rainfall data 2011 SR and 2012 LR Teso