CHARACTERIZATION AND EVALUATION OF LOCAL COWPEA ACCESSIONS AND THEIR RESPONSE TO ORGANIC AND INORGANIC NITROGEN FERTILIZERS IN COASTAL KENYA

BY

FRANCIS KANGETHE MUNIU

B.S.c (Hons) Nairobi

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DECLARATION

I declare that, this is my original work and has not been submitted for an award of a degree in any other University.

Francis Kang'ethe Muniu…………… Date…9/11/2017……………

This thesis is submitted with our approval as the University Supervisors

1. Prof. M. Jesang Hutchinson
Department of Plant Science and Crop Protection
University of Nairobi
Signature…………………………… Date…9/11/2017………

2. Dr. Jane Ambuko
Department of Plant Science and Crop Protection
University of Nairobi
Signature…………………………… Date…9/11/2017………

DEDICATION

To my wife Rosalia and my children Naomi and Joseph

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ABSTRACT

Cowpea is among the most popular indigenous African leafy vegetables grown and consumed as grain and leaf by poor small scale farmers in coastal Kenya. The major constraints in cowpeas production include unavailability of morphological and genetic characterization data and lack of technical packages along the value chain. The objectives of this study included: to collect and characterize vegetable cowpea accessions in coastal Kenya, to assess the leaf yield of the accessions and to determine response of select accessions to organic manure and inorganic nitrogen fertilizer application. Twenty eight cowpeas accessions collected from Kilifi and Mombasa counties in Coastal Lowland 3 and 4 ecological zones were evaluated at Kenya Agricultural Research and Livestock Organization (KALRO), Mtwapa. The design of the experiment was randomized complete block design with three replications. Morphological characterization was carried out using International Board of Plant Genetic Resources descriptors. Principle component analyses was conducted on the qualitative and quantitative characters. Cluster analysis was performed using agglomerative hierarchical clustering. The effect of four concentrations of cattle manure (0, 7.8, 15.6 and 23.3 tons/ha) and inorganic nitrogen (Calcium ammonium nitrate) application (0, 178, 416 and 555 kg/ha) on growth and fresh and dry leaf weights from one and serial harvests of four local vegetable cowpea accessions, was studied over two seasons. The experiment was laid in RCBD with three replications and treatments arranged in a factorial manner. Data was analyzed using GenStat Statistical package and means were compared using LSD at 5% level of significance (P=.05). The 28 accessions had sub-globose leaf shape, coriaceous leaf texture and were glabrescent. Twenty six had V-mark on leaflets, while two had none. The leaf colour ranged from dark green to pale green. Seventeen accessions had no twining tendency, two had intermediate and nine had slight twining tendency. The accessions flowered between 36 and 52 days after planting. The mean number of nodes was between 8-10 nodes per plant.

The variety Mnyenze madamada had the highest fresh weight yield while highest dry leaf yield was recorded in variety Katsetse. Ward’s method and Euclidian distance produced three clusters. PCA reduced the original set of twenty one variables to five Principal components (PCs), indicating approximately 81.10% of the entire genetic variation in five PCs. Incorporation on of cattle manure and inorganic nitrogen fertilizer CAN had positive influence on leaf dry and leaf yields. The best yields of 27.4 tons/ha were achieved in accession Usimpe mtu mdogo with application of CAN fertilizer at rate of 555kg/ha. Incorporation of 15.6 tons of manure in the soil resulted in best leaf yields of 23.6 tons/ha in Usimpe mtu mdogo. The yields were higher in second season. Dry weights of multiple harvests followed a similar trend Calcium ammonium nitrate was more effective compared to cattle manure during the dry season compared to the wet season, when cattle manure significantly increased yields (P>.05). The four select local cowpea accessions responded positively to the application of organic and inorganic fertilizers over seasons, and therefore, have the capacity to address food security and income generation challenges in ASAL and marginal parts of Kenya such as Kilifi County.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Kenya is among developing countries with high population growth rate of 2.6% (Knoema, 2016). The increasing population has resulted in an increased demand for food crops for most dietary requirements. A significant proportion of the population which includes children and women suffer from malnutrition because of food insecurity. This problem can be alleviated by use of indigenous crops (IPGRI, 2005). Vegetables are a key component in human diets. They are a source of protective nutrients especially vitamins and minerals, dietary fibre, proteins in addition to providing food (Grubben, 2000). Cowpea (*Vigna unguiculata*, L. Walp.) is a key African indigenous leafy vegetables (AILVs) consumed in Eastern and Southern Africa both as grain and leaf (Keller *et al.*, 2005). Cowpea has been widely produced mainly for its protein-rich pulse, popularly consumed with starchy staple foods. Its adaptability to drought prone areas, short maturity period and a variety of uses makes it a very attractive alternative crop for farmers in arid and semiarid regions with low and unreliable rainfall (Hallensleben *et al.*, 2009). Among the AILVS cultivated and utilized in the coastal region of Kenyan is cowpea. Cowpea is the most consumed vegetable in Kilifi County and the entire coastal region of Kenya (Muli and Saha, 2000). In the region, cowpea is a critical source of protein, especially for poor population in rural and metropolitan areas. Cowpea leaves are most commonly cooked to be served with maize meal (ugali) and other starchy foodstuffs such as cassava. It is also consumed fried or fresh in relish. Cowpea leaves can sometimes be dried, ground into a powder, and preserved for use in the dry season when fresh leaves are scarce (Bittenbender *et al.*, 1984; Imungi and Potter, 1983). Canning techniques have been developed for cowpea leaves (Imungi and Potter, 1985). Cowpea leaves, dried or fresh, are sold commonly in local and urban markets whenever available (Bittenbender *et al.*, 1984).

The main cowpea producing counties in Kenya are Kitui, Kisii, Migori, Kakamega, Bungoma, Machakos, Makueni, Kisumu, Kilifi, Kwale and Tharaka Nithi. In 2014 the largest quantity of cowpeas was produced in Kitui County, which produced 24% of national production. Other counties producing cowpea were Kilifi, Kwale, Migori, Kakamega, Bungoma, Kisumu, Siaya Makueni, Machakos and Tharaka Nithi. Total hectarage under cowpea leaf production was 24,431 ha and a production of 65,096 MT (AFFA, 2014). In Kenya cowpea is produced for the domestic market and is commonly referred to as 'Kunde'.

The major constraints facing the production of cowpeas in the coastal region include unavailability of quality seed, lack of technical packages along the entire value chain and general lack of awareness of the potential the crop holds in mitigating poverty and malnutrition challenges in the community. The cowpea, just like other AILVs is still viewed as a 'woman's' crop among rural communities. Women form the majority of the poor and yet dominate the vegetable production in these poor rural communities. To improve the productivity and quality of vegetable cowpea production, there is need to develop suitable varieties and sustainable agronomic production packages to be adopted by farmers.

1.2 Problem statement

Although cowpea is very important as a leafy vegetable in many African countries, it has been neglected in research and development programs (Barrett, 1990). In recent times, efforts have been made to initiate some research on some leafy African indigenous vegetables, but for cowpeas focus has been mainly on improvements of the pulse grain and entire plant for animal feed (Singh *et al.*, 2003). However the leaves require more attention since they have much potential for contributing to meet a portion of the greatly increased demands of nutrients that the world population needs.

In the coastal region of Kenya there are many cowpea accessions with potential for high yields of grain and leaf, tolerant to periods of low soil water availability and resistant to pests and diseases. Characterization and evaluation of performance of these accessions have not been conducted (Ndiso *et al.*, 2015). Variety development has mainly occurred for varieties with high yield of grain (Karanja *et al.*, 2008). Consequently there are few varieties recommended for use as vegetable cowpea. In the recent past, KARI has released high yielding cowpea varieties such as KVU and K-80 (Karanja *et al.*, 2008). The rate of uptake among farmers, however, has been low with farmers having a strong preference for local accessions that are said to be more palatable despite the low yields compared to the improved varieties. The need to collect local cowpea accessions being grown by farmers and characterize them is paramount. There is also need to evaluate the performance of various accessions for desirable attributes for leaf yield and quality.

A key constraint in small holder farms in coastal lowland of Kenya, is low soil productivity (Mureithi, *et al.*, 1996; Saha and Muli, 2000). The soils are inherently poor in fertility and have inadequate levels of major nutrients such as nitrogen and phosphorus. Most soils are also sandy and prone to loss of nutrients through leaching. Nitrogen is a key element in production of leafy vegetables (Onyango *et al.*, 2005). It promotes cell division and expansion in leaves and root development. Nitrogen can be sourced from artificial fertilizers and manures. A large number of farmers own cattle, goats and chicken that can produce manure for use in production of indigenous vegetables such as cowpeas. Few studies have been conducted to develop appropriate agronomic/ production packages for improved yields and nutrition of cowpeas.

1.3 Justification

Kenya has suffered from food insecurity mainly due to drought and over reliance on maize. Cultivation, processing and utilization of indigenous vegetables adaptable to local environment has the potential of improving food situation, nutrition and health of the people in the long run. Over the past fifteen years, consumers have started appreciating the value of vegetables for supply of important nutrients their health and medicinal use, resulting in increased demand for vegetables in formal and informal markets in urban centres in Kenya (Mwangi and Mumbi, 2006).

AIVs have good yield potential and are known to be nutritionally rich (Onyango *et al.*, 2004.) and if well utilized can address food insecurity and nutritional problems among rural populations. They are rich in proteins vitamins A and C, crude fiber, fat, calcium and iron. Nutritionist have assembled evidence showing that micro and macro nutrients malnutrition is a serious wide spread health problem in developing countries leading to "hidden hunger" (FAO, 19960). In Kilifi County malnutrition has been rampant over the years due to variability in crop production. An evaluation of the nutrition condition revealed cases of stunted, wasted and underweight under-five children to be 34.9%, 5.7% and 25.4% correspondingly (Republic of Kenya, 2002). Kilifi County has high average poverty and food insecurity figures ranging between 70 and 90% (Kenya Food Security Steering Group, 2011). Development of suitable varieties and appropriate production technologies of indigenous vegetables such as cowpeas would go a long way in improving food supply situation and economic welfare of the vulnerable population.

1.4 Objectives

1.4.1 General objective

The general objective of the study was to document morphological and agronomic attributes of existing vegetable cowpea accessions and develop appropriate agronomic production technologies in order to improve the productivity and quality of vegetable cowpea in the coastal region of Kenya.

1.4.2 Specific objectives

1. To collect and characterize vegetable cowpea accessions in Mombasa and Kilifi Counties in coastal Kenya.
2. To determine the effect of organic manure and inorganic nitrogen fertilizer rates on growth and leaf yield of selected vegetable cowpea accessions.

1.4.3 Hypothesis

1. There are no morphological differences among local cowpea accessions in coastal Kenya.
2. Incorporation of cattle manure and inorganic nitrogen fertilizer have no effect on growth and development of select local cowpea accessions from coastal Kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Cowpea is a key legumes which acts as an essential source of protein in the diets of people of developing countries. It is widely cultivated in the third world for its cheap source of proteins such as Lysine (Bressani, 1985) and acts as a supplement for meat, which is always in short supply. It is consumed as green leaves, green pods, green peas, dry grains and herbage as an animal feed. Cowpea is also used to constitute animal feeds such as hay, silage and pasture. It is also used in soil improvement as soil cover, green manure for maintaining soil fertility.

2.2 Botanical aspects of cowpeas, origin and regions of cultivation

Cowpeas is a dicotyledonous plant belonging in the order Fabales, family Fabaceae, sub-family Faboideae, tribe Phaseolae, sub-tribe Phaseolinae and genus Vigna and has the Scientific name *Vigna unguiculata* (Verdcourt, 1970; Padulosi and Ng, 1997). It is a widely adapted, versatile, and nutritious legume cultivated in many parts of the world. It is a dual purpose crop grown for grain and leaf. It is mainly grown in tropical climates since it requires high soil temperatures for good growth. It grows in a wide variety of soils ranging from heavy to light textured and from the humid tropics to the semi-arid tropics. There are several types of cowpeas. One is the trailing type that may also climb and twine around other plants. The trailing types are indeterminate in growth habits, and may grow for two or more seasons. Breeding and crop improvement efforts have resulted in development of erect types which are non-trailing and determinate in growth habit. Cowpea growth duration varies widely in different genotypes and is affected by environmental conditions. Average growing period from sowing to flowering ranges from 38 to 141 days. Generally cowpeas are photoperiod sensitive according to Wien and Summerfield (1980), who observed that they are generally quantitative short day plants with a tendency to flower as the days become shorter. (Crawford *et al*, 1997) found that day length above which flowering is delayed considerably varies with variety but approximates to 13.5 hours.

According to Ng and Padulosi, 1988, Cowpea is a native of Africa, with West Africa (Nigeria) being a major centre of diversity. A secondary centre of diversity could be India, since significant genetic variability occurs on the subcontinent (Pant *et al*., 1982). South-Eastern Africa has been recorded a key centre of diversity of the wild *Vigna* species (Padulosi *et al*., 1991). Ng and Marechal (1985) divided cowpeas into four cultigroups i.e. (1) *unguiculata*, which is the common form; (2) *biflora* or catjang, which is characterized by small erect pods and found mostly in Asia; (3) *sesquipedalis*, or yard-long bean, also mostly found in Asia and characterized by its very long pods which are consumed as a green pods; and (4*) textilis*, which is found in West African countries whose long peduncles were used for fibres.

Worldwide area of cowpea production is approximately 10.1 million hectares and global production approximately 4.99 million tons (FAOSTAT, 2008.) Africa produces large percentage of the world cowpea production, with Nigeria and Niger predominating. Other countries with substantial production of cowpea include Brazil, Haiti, India, Australia, the United States of America, Bosnia and Herzegovinea.

Cowpeas is grown primarily for its edible seeds, but in over18 countries in Africa, 7 countries in Asia and Pacific, young cowpea leaves are consumed (Duke, 1981; Barrett 1987, 1990). Cowpeas is ranked in the top four leafy vegetables used in many parts of Africa according to Barret, (1990). In many markets in Africa fresh and dried cowpea leaves are a common product. (Bittebender *et al*., 1984; Bittenbender, 1992). Use of preserved fresh leaves is not a widespread practice. However some research on preservation techniques has been conducted. Bittenbender (1992) studied the effects of varying temperatures and package ventilation on the storage life of fresh cowpea leaves and found that closed 2-mil polyethylene bag at 15-30°C were optimal for packaging fresh leaves. He noted that low temperatures of below 15°C maintained for 2-5 days caused chilling injury.

2.3 Genetic diversity of cowpea accessions

Characterization of genetic diversity among cowpea accessions is important in developing superior cultivars worldwide. This could be done through estimation of variation in phenotypic and qualitative traits such as flower colour, growth habit, or quantitative traits such as yield and stress tolerance (Kameswara, 2004). Some researchers have used as diversity as tool in classifying accessions and also to study taxonomic condition. A study on genetic diversity of cowpea lines collected from different agro-ecological zones in Kenya showed a relatively low level of genetic diversity among cowpea accessions. Kuruma *et al.*, 2010 found that Principal component analysis and clustering separated variability among the lines according to days of flowering, leaf length, leaf width, peduncle length, hundred seed weight and yield. Evaluation of cowpea genotypes for dry areas by Kenya Agricultural Research Institute resulted in recommendation of three varieties Machakos 66 (M66), Katumani 80 (K80)and KVU 27-1 (Karanja *et. al.*, 2008) for these areas. In a study on adaptability of cowpea lines in coastal Kenya (Weru, 2015), 16 genotypes were evaluated in three agro ecological zones: Coastal lowland 3 (Mtwapa), Coastal lowland 4 (Msabaha) and Coastal lowland 5 (Mariakani). The 16 genotypes attained maturity within 70 to 76 days after planting and were classified as early maturing types. Of the 16 genotypes tested in the three agro-ecological zones, five showed outstanding performance across the test environments. They were K005169, KVU 27-1, M66, K003962 and K046781. These genotypes manifested their adaptability and stability across test environments.

In participatory evaluation of cowpea landraces in Tezo, Kilifi County 11 cowpea varieties were evaluated using farmers criteria (Ndiso *et al.*, 2016). The varieties were evaluated at the following development stages: flowering, podding, maturity and post-harvest stages. Through use of high grain yield, drought tolerance, early maturity, ease of harvesting, leafiness and cooking duration, Farmers ranked variety Kutambaa, KVU 27-1, KVU 419, Kaima koko and Nyeupe as the top varieties.

In an assessment of genetic variability level in a collection of germplasm in Pakistan, (Imran *et al.*, 2010) found that the number of branches per plant showed a significant correlation (r=0.585) with leaf area but no significant correlation with pod length.

In a study of nutrient content of different accessions of two vegetable cowpea genotypes, climbing and prostrate, in Nigeria, Ano *et al.*, (2008), found that K content of the accessions varied with the types. In the climbing type, Akidienu, K level ranged from 1.25 to 1.52% while in the accessions of the prostrate type, Akidiani, the range was from 1.26 to 1.45%. In the prostrate type mean Phosphorus was lower than that obtained for climbing type. In climbing type, Protein contents ranged from 19.89 to 26.6% in the prostrate type and from 24.68 to 25.25%. For trace elements (Fe, Zn, Mn and Co), highest values were recorded for iron in the climbing genotype. It was observed that the prostate genotype had slightly lower amount of Fe with a mean value of 95. Results of this investigation indicate that climbing and prostrate cowpea genotypes had high in nutrient content. In a study on performance of three cowpeas varieties in Ghana, Addo-Quaye *et al.* (2011) found that growth parameters varied with variety and location with a linear increase in total dry matter production as plant density increased in the different locations.

2.4 Environmental Requirements of cowpeas

Cowpea is a vegetable crop which performs well in many areas of the humid tropics and some temperate zones. It does well in hot and dry environments, but it cannot tolerate of frost conditions. It germinates rapidly at temperatures above 36.1°C. Low temperatures result in slow germination rate.

Cowpeas can be cultivated under irrigation or in non-irrigated conditions. Cowpeas rainfall requirements fall between 400 to 700 mm per year. The plants have a great tolerance to water logging. For successful growth and development, rainfall for cowpeas should be well-distributed throughout the crop duration. The crop can be commercially produced in dry areas under irrigation. In comparison to other legumes, cowpea is more drought resistant than beans. Because of cowpeas tolerance to drought, it is has become a very prominent crop in many under developed regions of the globe. Irrigation results in high vegetative growth and delayed maturity. Water supply rates should be such that overwatering does not occur to avoid suppression of growth due to lowering of soil temperatures. For cowpeas most critical moisture requiring period is the period before flowering (TAB, 1974; Hall, 2004).

Cowpea can thrive on highly acid and neutral soil but is less well adapted to alkaline soils and does well in sandy loams or sandy soils with soil pH in between 5.5 and 6.5 (Duke and James, 1990).

2.5 Cowpea production systems

Cowpea is cultivated in two production systems (Saidi *et al.*, 2010a). In the first system the crop is grown purely as a vegetable. Under this system the whole plant is uprooted at the three to five true leaf stage when the leaves are tender and not very fibrous. In the second system the production is dual-purpose. In this system several sequential leaf pickings are made during the growth stage of the crop followed by harvesting of mature dry pods towards the end of the crop maturation period. The second system is the most widespread with small scale growers who usually grow cowpeas under an intercropping.

Sequential leaf harvesting was studied in Machakos County to investigate the effects of two harvesting cowpea regimes (7-days or 14-days interval on leaf vegetable) and grain yields. Comparison of profitability of sole dual-purpose cowpea and a dual-purpose cowpea-maize intercrop (Saidi *et al.*, 2010a) was also studied. The results showed that harvesting cowpea leaves at 7-days interval gave higher leaf vegetable yield under the two production systems. For rain yields, 14-days harvesting regime gave higher grain yields compared to 7-days leaf harvesting regime. The study showed that for farmers who want high yields of grain, no leaf harvesting should take place. Intercropping maize with cowpeas resulted in in high yields of maize yields where leaves of the cowpea crop were harvested at 7-days harvesting regime. In this study it was found that it is more profitable when leaves are harvested at 7-days interval. There was positive correlation with leaf vegetable and grain yields harvesting. Cow pea leaf production system under intercropping of cowpea with maize was found to have a higher gross margin as compared to a sole cropping systems.

2.6 Factors that affect cowpea leaf productivity

A variety of factors affect cowpea leaf productivity.

2.6.1 Leaf harvesting method

Leaf harvesting method is one of the factors that has been studied. The harvesting period for cowpea is 21-42 days (Bittenbender *et al.*, 1984), while cowpea seed harvest is 70-120 days (Duke, 1981). Cowpea grown solely for leaf harvest is harvested 3-6 weeks after planting. To establish the crop, one may choose to broadcast seeds alone or may broadcast in a field with a grain crop then thin at specified intervals. The uprooted plants can either be consumed or sold. When seeds are desired, leaf harvest should cease before pods enlargement (Barret, 1990). Cowpeas leave harvesting does not necessarily affect seed yield adversely especially for indeterminate types (Imungi and Potter, 1983; Akundabweni *et al.,* 1990). The effect of seed yield on leaf harvest is dependent on variety. Leafy determinate types are more severely affected by leaf harvest than those of indeterminate varieties (Wien and Tays, 1978). When targeting a seed crop in dual purpose system, timing of leaf removal may affect the plants ability to recover from leaf plucking. Removal of numerous young leaves may result in reduced seed yields. Under cowpea-maize intercropping system with maize, it was found that cowpea leaf harvesting resulted in an increase in productivity per unit area of land. Highest productivity was recorded with leaf harvesting initiated at 4 weeks after establishment (Saidi *et al.,* 2010a). In a study on effects of harvesting cowpea leaves at 7-days or 14-days interval on leaf vegetable and grain, yields of sole dual-purpose cowpea and intercrop with maize (Saidi *et al*., 2010b), 7-day harvesting interval produced higher yields in both sole and intercropping system. The 7-day harvesting interval regime also gave higher gross-margins with both cropping systems. Defoliation intensity and stage on performance cowpea for leaf production was evaluated by Ibrahim *et al.,* (2010) in Nigeria. Early defoliation significantly reduced yield and yield components. It was found that leaf removal lead to a significant loss in yield as as the percentage of leaf removal increased. There was a significant interaction between stage and intensity of defoliation for pod yield showing that to 50% defoliation at vegetative and flowering stage was adverse to yield of vegetable cowpea.

2.6.2 Application of nitrogen

In coastal lowland Kenya, low soil productivity has been found to be a key constraint in small holder farms (Mureithi, *et al.*, 1996; Saha and Muli, 2000). The coastal soils are low in fertility and have inadequate levels of major nutrients such as Phosphorus and Nitrogen. In many areas the soils are sandy and leaching may take place during heavy rains. Cowpea being a leguminous plant fixes its own nitrogen from the environment using its root nodules hence it does not require a lot of nitrogen fertilization. In areas with soils poor in nitrogen supply, application of little quantities of about 15 kg of nitrogen as a starter dose are necessary for a good cowpea crop. Too much nitrogen fertilizer application leads to luxuriant growth resulting high amount of foliage and low yield of grain. Application of N promotes production of tender and succulent leaves of cowpeas which are harvested and used as green vegetable before flowering, when leaf plucking ends. Leaf plucking may have negative affect on seed yield since it reduces photo-synthetic area. Addition of nitrogen may reduce the negative effects of leaf plucking on grain yield stimulating vegetable growth. In a study conducted in Swaziland where the effects of nitrogen application were investigated, it was found that additional nitrogen increased seed yield significantly (Dlamini and Edje, 1999). A study in Nigeria showed that application of NPK fertilizer in small quantities to cowpea was beneficial. It was also found to be genotype dependent (Abayomi *et al.*, 2008).

2.6.3. Application of manure

Animal manure incorporation in the soil provides a source of organic matter in the soil resulting in improved chemical, physical and biological properties of the soil and is also acts as a source of energy in the soil environment. The manures increase the soil water holding capacity as well as and cation exchange capacity (Nandwa, 1995). They constitute an essential source of Nitrogen for increased crop production. Vegetables such as cowpeas are characterized by their shallow rooting habit and rapid growth rate which has an effect on their nutrition. With high growth rates it is necessary to provide enough supply of nutrients throughout the growth period. These days consumer have become aware of the value of organically grown products which are relatively free of toxic residues and hence are friendly to the environment. Cowpea responds positively to manure application in the soil. A study conducted in Morogoro on use of poultry and goat manure on cowpeas showed that plant height was highest at 55 days after planting with an application of 8t/ha of both poultry and goat manures (Kisetu and Assenga, 2013). Another study in Sri Lanka showed that high cowpeas leaf yields were obtained through incorporation of chicken manure combined with inorganic fertilizer at the recommended rate. Goat and cattle manure were inferior to chicken manure (Yoganathan *et al.*, 2013). Studies have indicated that treating manure with EM (effective microorganisms) improves its quality and uptake of nutrients by cowpeas. In a study in Bangladesh, use of EM treated animal manures had a positive increase in leaf number, increased number of nodules, resulted in more pods per plant, yielded highest seeds per pod, greater weights for 100 seeds, higher yields and increased quality of seeds in comparison with chemical and non-fertilizer treatments (Shahardeen and Seran, 2013). In another study in Sri Lanka organic manures with EM, significantly increased the nodules, marketable green pod lengths and number, dry weight of plant herbage and marketable yield compared to chemical and non-fertilizer applications (Seran and Shahardeen, 2013). Plants fertilized with goat manure mixed with EM had highest nodule numbers, fresh and dry weight of marketable pods per plant as compared to those treated cattle or chicken manure EM component.

2.6.4. Water availabilityty

Cowpea adapts to drought situations than many other crops. It can survive under rainfall conditions ranging from 400mm to 750 mm annually. Cowpeas also thrive under conditions of water logged soils for a considerable duration before succumbing to water logging. However rainfall should be distributed evenly throughout the growing period. Cowpeas have the capacity to soil moisture effectively and are have higher tolerance to drought situations than other annual crops such as groundnuts, soya-beans and sunflower. In areas where annual rainfall is high e.g. Coastal Lowland 4 agro-ecological zone in Kenya, vegetable cowpeas can be established to coincide with rainfall peak period for maximum leaf production. Cowpeas respond to severe moisture stress through curtailing leaf growth and reducing leaf area through adjusting orientation of leaves and closing the stomatal orifices. Another mechanism of coping with water stress is flower and pod abscission in periods of acute moisture stress. This response also acts as a growth-limiting mechanism. All year round commercial production of cowpea would require supplemental irrigation during drought period. The crop can be supplied with 288mm of water as by Liyanange (2012). Water requirement of vegetable types with protracted and long fruiting phase is more than that of grain types.

CHAPTER THREE

3.0 MORPHOLOGICAL AND AGRONOMIC CHARACTERIZATION OF VEGETABLE COWPEA ACCESSIONS IN COASTAL KENYA

ABSTRACT

Cowpea is among the most popular indigenous African leafy vegetables grown and consumed as grain and leaf by poor small scale farmers in coastal Kenya. The major constraints in cowpeas production include unavailability of morphological and genetic characterization data. The objective of this study was to collect and characterize vegetable cowpea accessions in coastal Kenya and to assess their leaf yield potential. Twenty eight accessions collected from Kilifi and Mombasa counties in Coastal Lowland 3 and 4 ecological zones were evaluated at Kenya Agricultural Research and Livestock Organization, Mtwapa. The study was set in a randomized complete block experimental

design and accessions were replicated three times. International Board of Plant Genetic Resources descriptors were used for morphological characterization. Principle component analyses was conducted on the qualitative and quantitative characters. Cluster analysis was performed using agglomerative hierarchical clustering. The 28 accessions had sub-globose leaf shape, coriaceous leaf texture and were glabrescent. Twenty six had V-mark on leaflets, while two had none. The leaf colour ranged from dark green to pale green. Seventeen accessions had no twining tendency, two had intermediate and nine had slight twining tendency. The accessions flowered between 36 and 52 days after planting. The mean number of nodes was between 8-10 nodes per plant. The variety Mnyenze madamada had the highest fresh weight yield while highest dry leaf yield was recorded in variety Katsetse. Ward's method and Euclidian distance produced three clusters. PCA reduced the original set of twenty one variables to five Principal components (PCs), indicating approximately 81.1% of the entire genetic variation in five PCs.

3.1 Introduction

Cowpea is the most important grain legume in Kenya coming second after beans *(Phaseolus vulgaris)* (Muthamia and Kanampiu, 1996). The hectarage of cowpea leaf production in Kenya was estimated at 24,431 ha (AFFA, 2014). Because of its short maturation period, cowpea is sometimes called "hungry-season crop" since it is usually the first crop to be harvested as most cereals take longer to mature. Cowpea is crop that requires low inputs. Farmers may elect to use more inputs in order to harvest more grain – in case of inadequate cash and input scarcity – they may also pick fewer pods and leave the plant to give more leaves for consumption or sale as green leaves. The foliage can also be used to feed livestock for more meat and milk. Versatility in use makes cowpea an excellent crop for coping with the challenging changes in climatic conditions facing African farmers (Gomez, 2004).

In Kenya cowpea leaf is produced for the domestic market. It is commonly referred to as 'Kunde'. In 2014 the largest quantity of cowpeas was produced in Kitui, which produced 15,470MT. Other counties producing cowpea were Kilifi, Kwale, Migori, Kakamega, Bungoma, Kisumu, Siaya Makueni, Machakos and Tharaka Nithi (AFFA, 2014). There are many accessions of cowpeas cultivated and consumed as vegetables in coastal Kenya. Kutambaa, KVU 27-1, Nyeupe, Kaimakoko K80, KM66, Mwandatu and Nyekunde are some of the varieties grown by famers in Kilifi County (Ndiso *et al.*, 2016). Many accessions are utilized but they have not been characterized and evaluated for performance in yield and quality. This study was therefore carried out to bridge this gap in knowledge.

3.2 Materials and methods

3.2.1 Collection, preliminary screening and seed multiplication of cowpea accession

Cowpeas accessions grown and consumed as vegetables in coastal Kenya were collected between 4th -13th April 2012 from Kilifi and Mombasa counties within two major agro-ecological zones (AEZs) where the crop is grown. The two agro-ecological zones were Coastal Lowland 3 and Coastal Lowland 4 (Jaetzold *et al.*, 2012). The districts that fall under the two AEZs are Kilifi, Malindi, Magarini and Ganze in Kilifi County and Likoni in Mombasa County. Thirty six cowpea accessions were collected. The location of collection, agro-ecological zone and accession names of cowpea accessions used by local community members are shown in Table 1.

Table 1: Location of collection, agro-ecological zone and accession names of cowpeas collected in coastal Kenya.

County	Sub-county	Ward	Agro-ecological zone	Accession Name
Kilifi	Malindi	Kanyangwa	CL4	Kunde Kubwa za kigiriama

				Usimpe mtu
	Magarini	Fundisa	CL4	MM-01 Kaimakoko MM-04
	Magarini	Kambi waya	CL4	MM-03
	Malindi	Nguruni	CL3	Kunde nyekundu
	Malindi	Lango Baya	CL4	Kunde za kigiriama MLB-01 Mwandatu Kaimakoko MLB-06 MLB-05 MLB-07 MLB-03 MLB-02 MLB-01 Mwakipipi Mnyenze madamada Mnyenze Usimpe Mtu
	Ganze	Bamba	CL4	Mnyenze Katariko
		Ganze	CL4	Mtsemeri Mwandatu MG-01
		Vitengeni	CL4	VT-01 VT-02
	Bahari	Roka	CL3	Mesonje
	Chonyi	Chasimba	CL3	Charika Kiringo mawe Murahai Usimpe mtu Sura Mbaya Mnyenze
	Kikambala	Junju	CL3	Katsetse Mwandatu Kiringongo mawe Sura Mbaya Usimpe mtu kubwa Usimpe mtu mdogo
	Kikambala	Gongoni	CL3	Mnyenze
Mombasa	Likoni	Mtongwe	CL3	MLK-01 MLK-02

3.2.2 The Experimental Site

The collected accessions were planted at Kenya Agricultural Research and Livestock Organization (KALRO), Mtwapa on 7th and 8th May 2012 for seed multiplication to be used for variety evaluation. The experimental site is located at E 039° 44.680" and S 03° 54.954" which is in coastal lowland 3 (CL3) agro-ecological zone as described by Jaetzold *et al.* (2012). The soils in the site are sandy with a pH of 6.9. The mean annual rainfall is 1200mm and is bimodal with the long rainy season starting in April going up to August. The short rain season usually start in October and runs up to December. The site is at 30m above sea level.

International Board of Plant Genetic Resources descriptors for cowpeas (IBPGR, 1983) were used in morphological characterization of the accessions (Table 1). Out of the 32 accessions planted, 28 were selected for accession evaluation (Table 2). The four discarded were found to be duplicates.

3.2.3 Accessions Evaluation

The accessions were evaluated in field trials at KALRO Mtwapa. The experiment was laid out in Randomized complete block design experimental design with accessions replicated three times was used. The experiment was established on 16th October 2012. The 28 accessions were planted on 4m x 3m plots and a spacing of 60 cm x 30 cm was used. An experimental plot had a plant population of 67 plants (55,555 plant/ha). The following morphological characteristics were recorded: terminal leaflet shape, leaf texture, growth pattern, hairiness on leaves, leaf marking, leaf colour, growth habit plant vigor, twinning tendency, nodes number, days to 50% flowering and terminal leaf length.

Leaf yield assessment was started on 23rd November 2012 i.e. 39 days after planting. For single harvest yield assessment, nine plants per plot were uprooted and the following parameters recorded: plant height, canopy width, length of taproot, number of branches and leaves. The fresh leaf weight was measured. The leaves were dried in for 72 hours in an oven at 55° C for 72 hours and then weighed. For multiple harvest assessment, leaves from selected nine plants per plot were harvested weekly and weighed. After weighing, they were also dried for 72 hours at 55° C for dry matter determination. Six multiple harvests were realized.

Collected data was analysed using GenStat Statistical Programme, 14th Edition (Lane and Payne, 1996**).**

3.2.4 Farmer Selection

The top 10 highest yielding and performing accessions were ranked by farmers in a Focus-group discussion (FGD) held on 30th May 2013 with Bodoi Women group in Kikambala ward Kilifi county to determine the top four accessions to be subjected to the agronomic trials and seed bulking. The farmers' criteria of selection included the following characteristics: Taste, leaf texture, ease of cooking, leaf quantity and harvesting duration. The following accessions were selected: Mnyenze madamanda, Sura mbaya, Katsetse and Usimpe mtu mdogo.

3.2.5. Principal component analysis (PCA)

Principle component and cluster analyses was used to classify and measure the pattern of genetic diversity in the 28 cowpeas accessions using Ward's method (XLSTAT, 2014). Twenty one characters were used, 9 qualitative and 12 quantitative. Table 2 gives the trait descriptions for which Principle Component Analysis was conducted.

Table 2: Descriptors of cowpeas accessions evaluated in coastal Kenya (IBPGR, 1983)

Trait	**Type**	**Description of trait**
Shape of terminal leaflet	Qualitative	Globose shape Sub-globose shape Sub-hastate shape Hastate in shape
Leaf texture	Qualitative	Cariaceous

		Intermediate Membranous
Growth pattern	Qualitative	Determinate habit Indeterminate habit
Hairiness on leaves	Qualitative	Glabrescent Short appressed hairs Pubescent to hirsuite
Leaf marking	Qualitative	Presence or absence of a V shape on leaflet base
Leaf Colour	Qualitative	Pale green Intermediate green Dark green
Growth habit	Qualitative	Acute and erect branches Erect branches Semi-erect habit Intermediate habit Semi-prostrate habit Prostrate in growth habit Climbing habit
Plant Vigour	Qualitative	Vigorous Non–vigorous Intermediate Vigorous Very vigorous
Twinning tendency	Qualitative	None Slight Intermediate Pronounced
Nodes on main stem	Quantitative	Number recorded 3 – 4 weeks after sowing
Number of days 50% to flowering	Quantitative	Days recorded from sowing to 50% plants flowered
Terminal leaf length	Quantitative	Length of terminal leaflet whose shape was recorded
Plant height	Quantitative	Height of plant ground level to tip of terminal leaflet
Canopy width	Quantitative	Length across the longest branches
Root length	Quantitative	Length from soil line to the tip of tap-root
Branch number	Quantitative	Number of branches in the whole plant
Number of leaves	Quantitative	Total number of leaves recorded
Single harvest fresh weight	Quantitative	Fresh leaf weight measured from sample plants and converted in tons per hectare
Single harvest dry weight	Quantitative	Dry leaf weight measured from sample plants and converted in tons per hectare
Multiple harvest fresh weight	Quantitative	Cumulative fresh weight measured from sample plants and converted into tons per hectare
Multiple harvest dry weight	Quantitative	Cumulative fresh weight measured from sample plants and converted into tons per hectare

3.3. Results

The variety morphological characteristics were recorded using cowpea descriptors of International Board of Plant Genetic Resources (IBPGR, 1983).

3.3.1 Leaf morphology and growth pattern

All the 28 accessions showed no significant differences in their terminal leaflet shapes, leaf texture, growth pattern and hairiness of leaves (Table 3; Plate 1). The terminal leaflet shape was sub-globose; the leaf texture coriaceous, growth pattern indeterminate and the hairiness on leaves glabrescent

Table 3: Cowpea morphological characteristics: Terminal leaflet shape, leaf texture, growth pattern and hairiness on leaves

Accession No.	Accession	Growth pattern	Terminal leaflet shape	Leaf texture	Hairiness on leaves
1	Usimpe mtu mkubwa	Indeterminate	Sub-globose	Coriaceous	Glabrescent
2	Mwandatu	Indeterminate	Sub-globose	Coriaceous	Glabrescent
3	Mwakipipi	Indeterminate	Sub-globose	Coriaceous	Glabrescent
4	MM-01	Indeterminate	Sub-globose	Coriaceous	Glabrescent
5	Mrahai	Indeterminate	Sub-globose	Coriaceous	Glabrescent
6	MM-03	Indeterminate	Sub-globose	Coriaceous	Glabrescent
7	Kiringongo	Indeterminate	Sub-globose	Coriaceous	Glabrescent
8	Kunde kumbwa	Indeterminate	Sub-globose	Coriaceous	Glabrescent
9	VT-01	Indeterminate	Sub-globose	Coriaceous	Glabrescent
10	MM-05A	Indeterminate	Sub-globose	Coriaceous	Glabrescent
11	Usimpe mtu	Indeterminate	Sub-globose	Coriaceous	Glabrescent
12	Mnyenze mandamanda	Indeterminate	Sub-globose	Coriaceous	Glabrescent
13	VT-02	Indeterminate	Sub-globose	Coriaceous	Glabrescent
14	Katsetse	Indeterminate	Sub-globose	Coriaceous	Glabrescent
15	MM-05B	Indeterminate	Sub-globose	Coriaceous	Glabrescent
16	Kunde za kigiriama	Indeterminate	Sub-globose	Coriaceous	Glabrescent
17	Charika	Indeterminate	Sub-globose	Coriaceous	Glabrescent

18	Mtsemere	Indeterminate	Sub-globose	Coriaceous	Glabrescent
19	KVU	Indeterminate	Sub-globose	Coriaceous	Glabrescent
20	Katariko	Indeterminate	Sub-globose	Coriaceous	Glabrescent
21	Mnyenze	Indeterminate	Sub-globose	Coriaceous	Glabrescent
22	Mesonje	Indeterminate	Sub-globose	Coriaceous	Glabrescent
23	MLB-07	Indeterminate	Sub-globose	Coriaceous	Glabrescent
24	Sura Mbaya	Indeterminate	Sub-globose	Coriaceous	Glabrescent
25	MG-01	Indeterminate	Sub-globose	Coriaceous	Glabrescent
26	Usimpe mtu mdogo	Indeterminate	Sub-globose	Coriaceous	Glabrescent
27	MLK-02	Indeterminate	Sub-globose	Coriaceous	Glabrescent
28	MLB-06	Indeterminate	Sub-globose	Coriaceous	Glabrescent

Plate 1. Sub-globose shape of cowpeas terminal leaflet

The local cowpea accessions differed in their leaf marking, leaf colour and growth habit (Table 4). Twenty six varieties had V-mark on leaflets, while two had none. The leaf colour ranged from dark green to pale green. Twenty accessions had intermediate green colour, seven had dark green while 1 was pale green.

Table 4: Cowpea morphological characteristics: Leaf marking, leaf colour and growth habit

Accession No	Accession	Leaf marking	Leaf Colour	Growth habit

1	Usimpe mtu kubwa	Abscent	Intermediate green	Semi- erect
2	Mwandatu	Present	Intermediate green	Acute erect
3	Mwakipipi	Present	Intermediate green	Acute erect
4	MM-01	Present	Intermediate green	Intermediate erect
5	Mrahai	Present	Intermediate green	Intermediate erect
6	MM-03	Abscent	Intermediate green	Acute erect
7	Kiringongo mawe	Present	Dark green	Acute erect
8	Kunde kubwa	Present	Pale green	Semi-erect
9	VT-01	Present	Intermediate green	Intermediate
10	MM-05A	Present	Intermediate green	Semi-erect
11	Usimpe mtu	Present	Intermediate green	Acute
12	Mnyenze madamada	Present	Intermediate green	Intermediate
13	VT-02	Present	Intermediate green	Acute erect
14	Katsetse	Present	Intermediate green	Semi-erect t
15	MM-05B	Present	Dark green	Acute erect
16	Kunde za kigiriama	Present	Intermediate green	Intermediate
17	Charika	Present	Intermediate green	Acute erect
18	Mtsemeri	Present	Dark green	Intermediate
19	KVU	Present	Dark green	Acute
20	Katatariko	Present	Dark green	Intermediate
21	Mnyenze	Present	Intermediate green	Intermediate
22	Mesonje	Present	Intermediate green	Erect
23	MLB-07	Present	Dark green	Intermediate
24	Sura mbaya	Present	Intermediate green	Intermediate
25	MG-01	Present	Dark green	Erect
26	Usimpe mtu mdogo	Present	Intermediate green	Intermediate
27	MLK-02	Present	Intermediate green	Acute

28	MLB-06	Present	Intermediate green	Acute

The 28 local cowpea accessions that were collected in Coastal Kenya exhibited different growth habits: 7 % had erect, 11% had semi erect, 39% had intermediate and 39 % had acute erect growth habits (Figure 1).

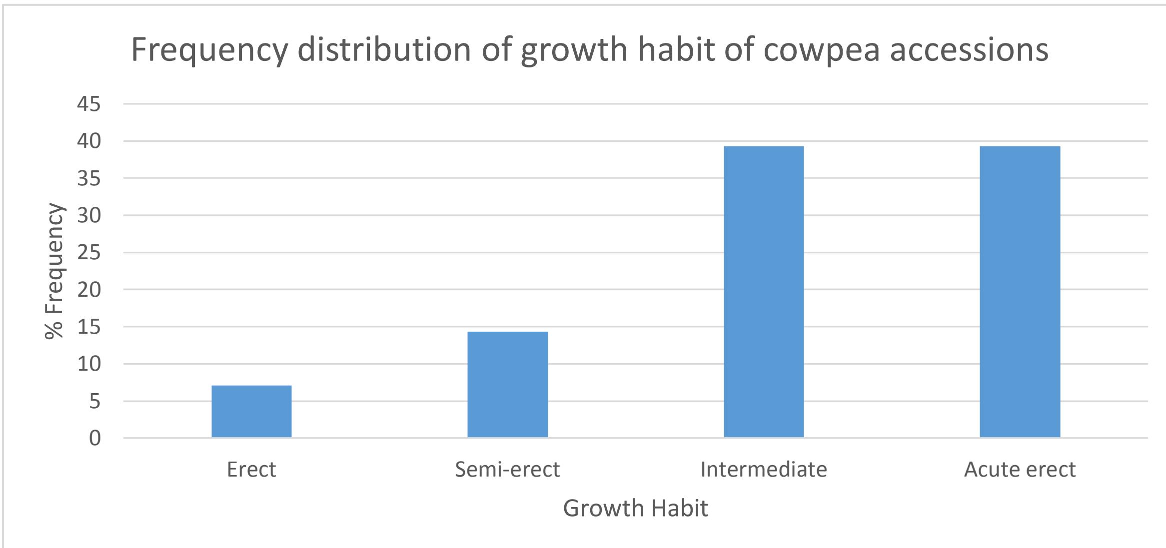

Figure1: Cowpea accessions growth habit Frequency distribution

3.3.2 Twining tendency, nodes number, days to 50% flowering and terminal leaflet length

The 28 local cowpea accessions exhibited different twinning tendencies, number of nodes, and number of days to flowering and terminal leaf length (Table 5). Seventeen accessions (61%) had no twining tendency, two (7%) had intermediate and nine (32%) had slight twining tendency. The study shows most of the accessions need no staking since majority did not show twining tendency. Most of the cowpea accessions observed formed 8-10 nodes per stem but showed no significant difference among them. The number of days from emergence to 50% flowering varied with accessions. Four accessions flowered 36 days after sowing, eleven after 41 days, 3 after 44 days, one after 45 days, 6 after 47 days while the last accession flowered after 52 days from date of sowing.

Table 5: Cowpea morphological characteristics: Twinning tendency, number of nodes, number of days to 50% flowering and terminal leaf length

No.	Accession Name	Twining tendency	Nodes Number	Days to 50% flowering	Terminal leaf length
1	Usimpe mtu mkubwa	Slight	9	41	133.5
2	Mwandatu	Slight	9	45	110.5
3	Mwakipipi	None	9	47	150.5
4	MM-01	Slight	8	36	134
5	Mrahai	None	9	47	127
6	MM-03	None	10	47	110
7	Kiringongo mawe	None	9	36	132.5
8	Kunde kubwa	None	9	36	118.5
9	VT-01	None	9	41	123.5
10	MM-05A	Slight	9	41	137
11	Usimpe mtu	Slight	9	41	131
12	Mnyenze madamada	None	10	44	123.5
13	VT-02	None	9	36	111
14	Katsetse	None	10	41	133.5
15	MM-05B	Intermediate	9	41	130
16	Kunde za kigiriama	Slight	9	41	137.5
17	Charika	None	9	47	112.5
18	MtsemerI	None	8	44	153
19	KVU	None	8	52	127.5
20	Katatariko	None	9	41	132.5
21	Mnyenze	Slight	9	45	131
22	Mesonje	None	9	47	128
23	MLB-07	None	9	44	131.5
24	Sura Mbaya	None	10	52	139
25	MG-01	Slight	9	41	130
26	Usimpe mtu mdogo	Slight	9	47	128
27	MLK-02	None	9	41	151.5
28	MLB-06	Intermediate	9	41	126.5
	LSD		**0.71**	**0.18**	**9.5**

3.3.3 Plant height, canopy width, root length, branch and leaf numbers

The accessions plant heights had significant differences at 5% level of significance (Table 6). The tallest accessions was Mnyenze madamada at 67.2 cm while the shortest were MM-05A at 33 cm. The accessions with the widest canopy included MLK-02 (135 cm), MLB-07 (129.4), Mnyenze

(128.8 cm) and Kunde kubwa (120.2), while those with the narrow canopy included Mwandatu and MG-01 of around 57cm. The root lengths also varied from 10.4cm to 37.7 cm in MM-05 and KVU, respectively with some indicating elaborate nodulation (Table 6; Plate 2). There were slight differences in the number of branches among the accessions and ranged between 5 and 9 branches per plant. Katsetse was the leafiest of the accessions with over 98 leaves per plant while MM-05A had 50.

Table 6: Cowpea morphological characteristics: Plant height, canopy width, root length, number of branches and number of leaves of 28 cowpeas accessions 6 weeks after sowing

	Accession	Plant height (cm)	Canopy width (cm)	Tap Root length (mm)	Branch Numbers	Leaf Numbers
1	Usimpe mtu mkubwa	65.2	114.8	21.0	7	79
2	Mwandatu	34.0	57.0	14.9	5	54
3	Mwakipipi	48.0	89.3	12.1	8	76
4	MM-01	63.3	109.0	18.3	6	77
5	Mrahai	39.3	89.6	14.9	6	59
6	MM-03	54.2	111.4	16.5	8	93
7	Kiringongo mawe	59.4	108.8	18.0	7	84
8	Kunde kubwa	63.5	120.2	20.2	8	88
9	VT-01	52.1	83.8	15.9	7	79
10	MM-05A	33.2	117.6	10.4	5	50
11	Usimpe mtu	39.8	69.3	13.2	5	53
12	Mnyenze madamada	67.2	114.3	20.9	9	84
13	VT-02	59.5	106.6	19.2	8	90
14	Katsetse	57.3	102.1	18.8	8	98
15	MM-05B	61.9	61.9	20.1	8	86
16	Kunde za kigiriama	63.3	114.1	18.7	8	87
17	Charika	40.0	70.5	17	7	70
18	Mtsemeri	40.8	66.7	18.2	8	57
19	KVU	53.3	93.4	37.7	6	65
20	Katatariko	60.3	111.9	18.5	7	76
21	Mnyenze	57.8	128.8	19.4	7	80

22	Mesonje	53.0	101.1	19.3	7	73
23	MLB-07	57.3	129.4	18.1	8	76
24	Sura mbaya	60.3	119.9	17.5	8	89
25	MG-01	57.6	57.6	20.8	7	83
26	Usimpe mtu mdogo	56.1	126.9	19.5	9	90
27	MLK-02	58.1	135.8	19.1	7	93
28	MLB-06	56.8	113.2	21.3	7	79
	LSD (p=0.05)	**16.5**	**46.1**	**33.2**	**1.6**	**22.1**

Plate 2: Rooting of Local Cowpea Accessions Mnyenze madamada, KVU-KARI and Kunde Kubwa

3.3.4 Fresh and dry leaf weight assessment of cowpea accessions

Of the evaluated local cowpea accessions, Mnyenze madamada and Katsetse were the highest fresh and dry weight yielders from single harvests (Table 7). Mesonje had the highest fresh and dry weights from multiple harvests. Mesonje had the highest fresh weight yield. Other accessions that performed well in fresh and dry leaf yield are MLK 02, Katsetse and Sura mbaya.

Table 7: Fresh and dry leaf yield for single and multiple harvests of cowpea accessions at Mtwapa

Accession Name	Single harvest Fresh weight (tons/ha)	Single Harvest (Dry Weight (tons /ha)	Multiple Harvest-Fresh Weight (tons/ha)	Multiple Harvest-Dry Weight (tons/ha)
Usim mtu kubwa	5.2	0.7	18	2.4
Mwandatu	2.8	0.3	11.4	1.4
Mwakipipi	5.9	0.7	20.8	2.5
MM-01	5.4	0.7	18.1	2.1

MRAHAI	3.7	0.4	9.5	1.3
MM-03	5.7	0.7	17.7	2.2
Kiringongo mawe	6	0.8	16.5	2.4
Kunde kubwa	6.3	0.8	18.7	2.3
VT-01	5.3	0.7	15.1	2.1
MM-05A	3.6	0.4	9.3	1.1
Usimpe mtu	4	0.6	13.2	1.8
Mnyenze madamada	8.1	0.9	19.5	2.4
VT-02	5.4	0.6	17.6	2.3
Katsetse	7.9	1	22.5	2.7
MM-05B	5.6	0.6	18.7	2.5
Kunde za kigiriama	5.7	0.8	17.1	2.3
Charika	3.5	0.4	14.8	1.9
Mtsemeri	3.9	0.5	18.1	2.1
KVU	4.7	0.5	17.1	2.2
Katatariko	5.7	0.7	18.6	2.3
Mnyenze	6.5	0.7	17.7	2.2
Mesonje	6	0.7	23.3	2.7
MLB-07	6	0.7	21.5	2.6
Sura Mbaya	6.5	0.7	22.7	2.7
MG-01	6.4	0.7	17.7	2.4
Usimpe mtu mdogo	6.2	0.7	20	2.6
MLK-02	7.3	0.6	20.6	2.5
MLB-06	4.9	0.6	17.5	2.3
LSD (p=0.05)	**1.63**	**0.22**	**5.7**	**0.72**

3.3.5 Farmers' assessment of cowpea accessions

The top 10 highest yielding and performing accessions were ranked by farmers in a Focus-group discussion (FGD) held on 30th May 2013 with Bodoi Women group in Kikambala ward Kilifi county to determine the top four accessions to be subjected to the agronomic trials and seed bulking. The farmers' criteria for selection included the following characteristics: Taste, leaf texture, ease of cooking, leaf quantity and harvesting duration. Accessions Mnyenze madamada, Sura mbaya, Katsetse and Usimpe mtu mdogo (Plates 3-6) were ranked best by farmers.

Plate 3: Accession Sura mbaya

Plate 4: Accession Mnyenze madamada

Plate 5: Accession Usimpe mtu mdogo

Plate 6: Accession Katsetse

3.3.6 Principal Component Analysis of cowpeas accessions

Table 8 shows the results of principal component analysis (PCA) of qualitative and quantitative characters of the 28 cowpea accessions evaluated. PCA reduced the original set of twenty one variables to five Principal components (PCs), indicating about 81.1% of the entire genetic variation in five PCs. Proportions of variations were derived from the first five PC axes, with Eigen values of 1 or greater. The first 3 principal components explained 64.8% variation, while the first PC accounted for 31.44%, the second 22.70% and the third 10.69% (Table 8). Principal component one (PC 1) had Eigen-value of 5.345 which was the largest and accounted for the greatest amount of variance in the original data set. PC 2 accounted for the greatest amount of variation in the residual variation unaccounted for by the first principal axis. Similarly PC 3 accounted for the greatest amount of variation in the residual variation unaccounted for by PC2 with the same process unfolding for principal axes 4 and 5.

Table 8: **Principal Component Analysis (PCA) of 28 vegetable cowpea accessions evaluated in coastal Kenya**

Principal Component analysis	**PRINCIPAL COMPONENT AXIS**				
	PC1	**PC2**	**PC3**	**PC4**	**PC5**
Eigen value	5.345	3.860	1.818	1.527	1.237
Proportion of variation explained (%)	31.443	22.704	10.693	8.984	7.279
Cumulative % proportion of variation	31.443	54.147	64.839	73.823	81.102
TRAITS	**EIGEN VECTORS**				
Leaf marking	0.039	-0.016	0.434	-0.066	0.353
Leaf colour	0.131	-0.037	0.491	0.220	0.039
Growth habit	-0.040	-0.162	0.018	0.432	0.364
Plant vigor	0.200	0.085	0.137	-0.102	**0.609**
Twinning tendency	0.094	-0.198	-0.041	-0.551	-0.125
No. of nodes	0.000	0.255	-0.483	0.136	0.062
Number of days to flowering	0.118	-0.065	-0.060	0.575	-0.323
Terminal leaf length	0.006	0.099	0.504	-0.080	-0.487
Plant height	0.422	-0.092	-0.018	-0.037	-0.022
Canopy width	0.414	-0.075	-0.031	-0.087	-0.017
Root length	0.416	-0.105	-0.003	-0.004	-0.037
Number of branches	0.411	-0.111	-0.014	0.056	-0.047
Number of leaves	0.413	-0.089	-0.147	0.025	0.020
Single harvest Fresh weight	0.136	0.457	-0.056	-0.085	0.044
Single Harvest Dry Weight	0.061	0.463	-0.048	-0.192	-0.004
Multiple Harvest-Fresh Weight	0.133	0.432	0.127	0.142	-0.044
Multiple Harvest-Dry Weight	0.124	0.438	0.119	0.117	-0.020

In PC1 the greatest contribution to variation came from plant height, tap root length, branch numbers, leaf numbers, canopy width, leaf colour, twining tendency, days to 50% flowering, leaf marking, nodes, length of terminal leaf and growth habit in that order. For PC2, the parameters which had the highest contribution in decreasing order were number of nodes, leaf marking, terminal leaf length, leaf colour, plant vigour, days to 50% flowering, leaves, growth habit, twining tendency, branches, tap root length, canopy width and plant height. In PC2, twinning tendency, days to 50% flowering, growth habit, leaf colour, nodes, canopy width, branches, leaf marking, length of terminal leaf, plant height, plant vigour, plant height number of leaves and root length had the highest contribution in that order (Figure 2).

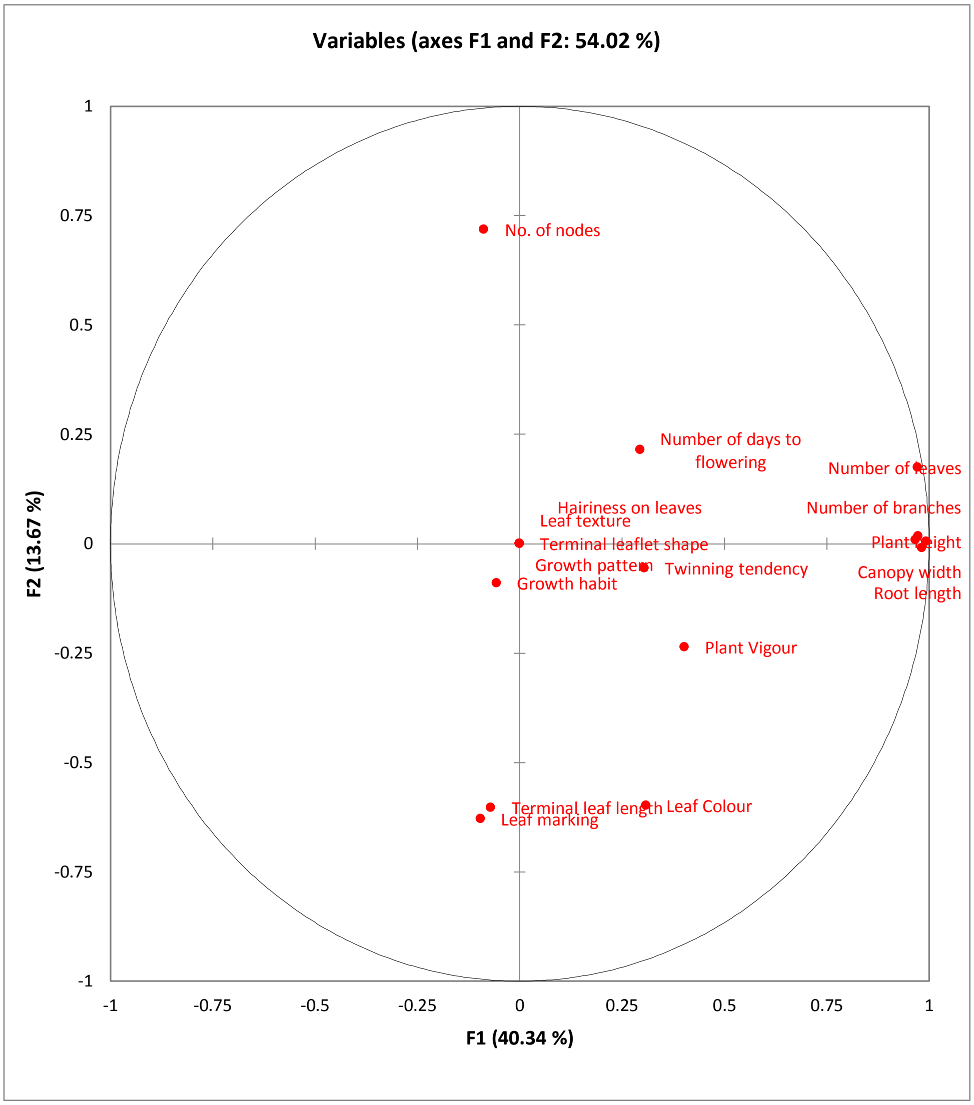

Figure 2: Contribution of cowpea morphological characters to variation in PC1

In PC1 the accessions which contributed highest to the variation were Mnyenze, MLB-07, MG-01, and Usimpe mtu mdogo, MM-03, Mwandatu, KVU and Mtsemere in that order. The accessions which had highest contribution in PC2 in decreasing order were MM-03, Usimpe mtu mkubwa, Mnyenze madamada, Kunde kubwa, Sura mbaya, Charika, Katesetse, Mwandatu, VT-01, Mrahai, VT-02, Mnyenze, Usimpe mtu mdogo, and Mesonje. In PC3 highest contribution to variation was contributed by MM-01, Usimpe mtu mkubwa, Kunde za kigiriama, Kunde kubwa, MM-05A, MG-01, Mnyenze, Usimpe mtu, Mwandatu, VT-01, Usimpe mtu mdogo, MLB-06, Mesonje and VT-02.

The variables with high scores (>0.20) on PC 1 were: plant height, canopy width, root length, branches and leaves and they were quantitative traits. The variables which had highest scores on PC 2 were: single harvest fresh weight, single harvest dry weight, multiple harvest fresh weight and multiple harvest dry weight. Hence, the variables which had high coefficient in first and second principal components were presumed the most relevant as they explained over half of the total variation. Plant vigour had the highest Eigen vector of 0.609 in PC 5 as shown with bold in Table 8. The characters with Eigen vectors of 0.60 and above are considered very important for their large effect contribution to variation.

The characters on PC 3 which had high coefficient (>0.20) scores were: leaf marking (0.43), terminal leaf length (0.5) and leaf colour (0.49) The fourth axis (PC 4) had the highest coefficient for growth habit (0.43), and leaf colour (0.22). The fifth axis (PC 5) had the high scores leaf marking (0.35) growth habit (0.36) and plant vigour (0.6).

Terminal leaflet shape, leaf texture, growth pattern and hairiness on leaves had no variation. The variables in the table 8 are the ones which contributed to the variations seen in the cowpeas accessions. Accessions with high PC1 scores could be good genitors for diversity. The rich diversity within the accessions provides more selection chances in breeding.

3.3.7 Dendrogram of quantitative and qualitative morphological characters of cowpeas accessions

Agglomerative hierarchical clustering, Ward's Method and Euclidian Distance to perform cluster analysis on the accessions in accordance with their variability using Accessions where data were missing were not included in the clusters. Figure 3 shows dendrogram based on this analysis for the accessions.

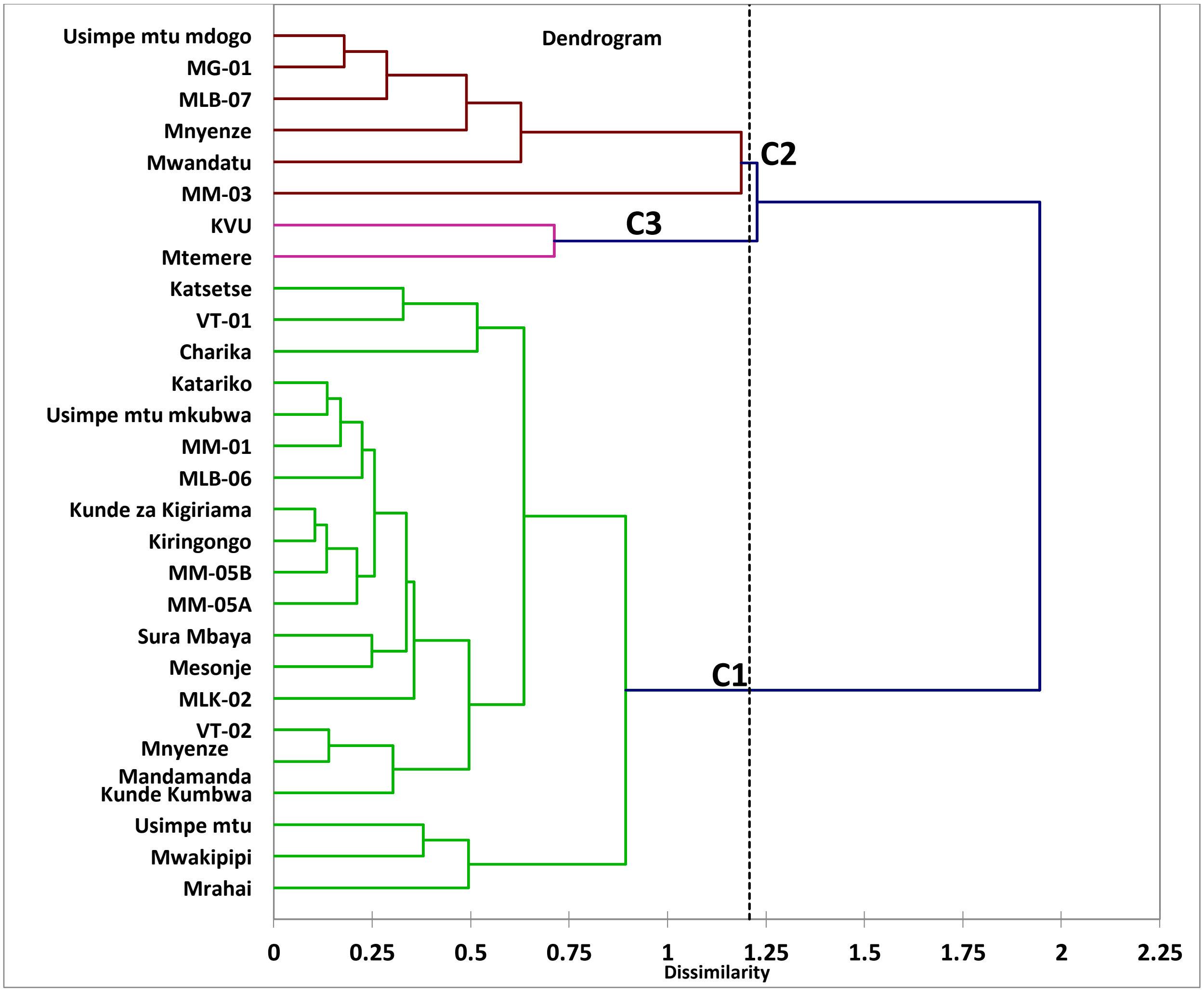

Figure 3: Dendrogram based on quantitative and qualitative traits of 28 cowpea accessions evaluated at KALRO-Mtwapa

The distance or dissimilarity between clusters is shown by the horizontal axis of the dendrogram while the vertical axis represents the accessions and cluster groups. The joining of clusters is shown on the graph by the splitting of a horizontal line into two horizontal lines. The distance (dissimilarity) between the clusters is represented by the horizontal position of the split, shown by the short vertical bar. The variability of both qualitative and quantitative characters was most important in clustering of the accessions according to dissimilarity. Three groups were clustered as a result of this cluster analysis, Cluster 1, 2, and 3 (C1, C2 and C3) as shown in Figure 3. Cluster 1 was the biggest with 16 accessions. VT-01 and Kunde kubwa, MLB-06 and VT-02, Katariko and MM-05B, Kunde za kigiriama and MM-01, Sura mbaya and Mesonje, Katsetse and Mnyenze madamanda were the most similar. There were four outliers, Mwakipipi, Usimpe mtu mkubwa, Kiringongo and Usimpe mtu, which are joined arbitrarily at much higher distances than the groups they are attached to in this cluster. Cluster 2 (C2) had 7 accessions. The most similar accessions in this cluster were Usimpe mtu mdogo and MLB-07 and KVU and Mtsemere. There were three outliers in this cluster: MG-01, Mnyenze and MM-03. Cluster 3 (C3) was the smallest with only four accessions. MM-05A and Mwandatu, Charika and Mrahai were the most similar. There were no outliers in this cluster.

3.4 Discussion

In this study it was established that there are many cowpeas accessions utilized as vegetables in Kilifi and Mombasa counties. Different accessions are available in the two major agro-ecological zones CL3 and CL4. The twenty eight accessions evaluated varied in morphological qualitative and quantitative traits. All the 28 vegetable cowpea accessions had sub-globose leaf shape, coriaceous (leathery) leaf texture and were glabrescent (nearly hairless). Terminal leaflet shape, leaf texture, growth pattern and hairiness on leaves had no variation. These traits did not contribute to the variations seen in the cowpeas accessions. The similarity of the accessions collected from different areas and agro-ecological zones indicate that farmers look for similar traits when selecting vegetable cowpeas for production.

The growth habit of cowpea is an important parameter in the crop cultivation practices to be adopted by farmers (Bennet-Larty and Ofori, 1999). Seventeen accessions (61%) had no twining tendency, two (7%) had intermediate and nine (32%) had slight twining tendency. A majority of the accessions showed no twining tendency hence staking may not be required indicating farmers prefer non-staking types of vegetable cowpea. Cobbinah *et al.,* (2011) obtained similar results from 134 accessions tested from 8 regions of Ghana. The mean value of around 42 days to 50% flowering obtained in this study indicates early flowering trait in the accessions. Similar results were reported on local Ghanaian cowpea accessions which flowered 39.5 days after planting (Cobbinah *et al*, 2011). Early flowering affects leaf production period by reducing the number of harvest that can be achieved during the growth period. Studies by Erskine and Khan (1978) showed there exists heterosis for earliness with early maturity being dominant over late maturity. Mak and Yap (1980) reported similar results.

Depending on availability of resources such as water and fertilizers, some accessions could respond better than others while some could be potential varieties for drought tolerance studies. These results indicate that there may be little genetic variations between the accessions attributes such as plant height, canopy width, and root length, branches, leaves and nodes. Environmental factors may be a factor when say the number of branches are compared to those of accessions studied in Ghana (Cobbinah *et al.*, 2011) where accessions had less than 5 branches.

Many researcher have conducted studies on cowpea using morphological traits such as plant pigmentation, plant habit, root traits, leaf traits, pod traits, seed traits, grain quality, and yield. In one of such studies, morphological diversity was used to study taxonomic relationships between genotypes belonging to the genera *Phaseolus* and *Vigna,* by Marechal *et al*., (1978). Morphological traits that included plant height, number of leaves, leaf length, the number of pods per plant, pod length and number of seeds per pod were used by Obute (2001) to characterize an aneuploidy *Vigna unguiculata* from other genotypes The studies showed that the traits were of great importance in distinguishing genetic variability and have led to a better classification of cowpea genotypes (Magloire, 2005).

Quantitative traits, such as yield performance and quality characters are of key significance in breeding and hence are given high priority in breeding programmes. Of importance to note, these traits are strongly affected by environmental conditions and also genotype with environmental interaction. Weru (2015) studied adaptability and stability of cowpea lines in Kenyan coast. Of the 16 genotypes tested in the three agro ecological zones of the lowland coast region, five have showed outstanding performance across the test environments. They are K005169, KVU 27-1, M66, K003962 and K046781. These genotypes could be evaluated with genotypes in the present study.

The distribution of the accessions on PC 1 and PC2 plot showed that morphological variation among the cowpeas does not exist. This indicates good traits for instance drought resistance are still retained within the accessions. Accessions Mnyenze madamada, which is more common in the drier agro-ecological zone, CL4, Sura mbaya, Katsetse and Usimpe mtu mdogo, more common in the wetter agro-ecological zone, CL3, were identified as most suitable accessions through variety evaluation and farmers' criteria that took into account taste, leaf texture, ease-of cooking, leaf quantity and harvesting duration.

3.5 Conclusion

In conclusion, most of the 28 local cowpea accessions collected from farmers in the two agro-ecological zones in coastal part of Kenya, exhibited vigorous growth with acute/intermediate erect growth habit with no or slight twining tendency. Although differences were noted in some morphological and agronomic traits studied, clustering of the accessions indicated no genetic variations among them.

CHAPTER FOUR

4.0 EFFECT OF CATTLE MANURE AND CALCIUM AMMONIUM NITRATE ON GROWTH AND LEAF YIELD OF LOCAL COWPEA ACCESSIONS IN COASTAL KENYA

ABSTRACT

Cowpea is among the most popular indigenous African leafy vegetables grown and consumed as grain and leaf by low income small scale farmers in coastal Kenya. The major constraints in cowpeas production include unavailability of morphological and genetic characterization data and lack of technical packages along the value chain. The objective of this study was to determine response of select accessions to organic manure and inorganic nitrogen fertilizer application. The effect of four levels of cattle manure (0, 7.8, 15.6 and 23.3 tons/ha) and inorganic nitrogen (Calcium ammonium nitrate) application (0, 178, 416 and 555 kg/ha) on growth parameters and fresh and dry leaf yields from single and multiple harvest of four local vegetable cowpea accessions, was studied over two seasons. Design used was randomized complete block with treatments replicated three times and treatments arranged in a factorial manner. Data was analyzed by GenStat Statistical package and means compared by LSD at 5% level of significance. Incorporation on of cattle manure and inorganic nitrogen fertilizer CAN had positive influence on leaf dry and leaf yields. The best yields of 27.4 tons/ha were achieved in accession Usimpe mtu mdogo with application of CAN fertilizer at rate of 555kg/ha. Incorporation of 15.6 tons of manure in the soil resulted in best leaf yields of 23.6 tons/ha in Usimpe mtu mdogo. The yields were higher in second season. Dry weights of multiple harvests followed a similar trend Calcium ammonium nitrate was more effective compared to cattle manure during the dry season compared to the wet season, when cattle manure significantly increased yields (P>.05). The four select local cowpea accessions responded positively to the application of organic

and inorganic fertilizers over seasons, and therefore, have the capacity to address food security and income generation challenges in ASAL and marginal parts of Kenya such as Kilifi County.

4.1 Introduction

Cowpeas is the most important legume crop in coastal Kenya, which is principally grown under intercropping with maize and/or cassava for supply of vegetable and grain after maturity. It is also grown in pure stands for commercial vegetable production. Besides being an important source of cheap protein, cowpea is a reliable source of income from sale of leaves as vegetables. Sale of cowpea leaves is dominated by women who harvest the leaves from their farms or buy from other farms to sell to urban consumers.

Kenya's population has been rapidly increasing leading to intensification in cultivation of food crops (Hudgens, 1996) hand in hand with a reduction in arable farm sizes. The consequence of this has been depletion of soil fertility in many farms. Participatory rural appraisals and formal diagnostic surveys (Mureithi *et al.,* 1996) have confirmed this decline. The resultant effect of declining soil fertility is the main cause of low soil productivity in small holder farms in the region. Inadequate use of farm inputs as well as inadequate knowledge on use of various sources of nutrients has also contributed to decreasing farm productivity. Low soil productivity is a major constraint in agricultural production in small scale farms in the coastal region of Kenya. The situation is worsened by the low inherent fertility status of the coastal soils. Being mainly re sandy, the soils are easily leached, lowering their fertility. The practice of burning crop residues during land preparation has also causes further decline in the fertility of coastal lowland soils. Studies on use of various nutrients sources for improvement of crop productivity have been conducted mainly on maize (Saha and Muli, 2000).

Animal manures provides a reasonable source of organic matter in the soil and assist in improving chemical, physical and biological properties of the soil and also act as a source of energy in the soil environment. The animal manures can uplift the water holding capacity and its cation exchange capacity (Nandwa, 1995) in addition to being an important contributor to nitrogen for crop production. The use of organic manures is an emerging need in organic farming especially these days when consumers are more conscious of food safety and health concerns. Some vegetables such as cowpeas have shallow roots habit and grow rapidly. These characteristics necessitate adequate supply of nutrients in the top soil throughout the vegetative period.

Plants require larger amounts of nitrogen as compared to larger other elements. Deficiency in nitrogen supply in the soil leads to stunted growth and chlorotic leaves due to low assimilate formation. Low assimilate formation results in premature flowering and shortening of growth cycle. Excessive nitrogen enhances the development of the above ground foliage with abundant dark green tissues with high levels of chlorophyll and soft consistency and relatively poor root growth. Nitrogen fertilizer use has been shown to increase cowpea leaf yield (Abayomi *et al.,* 2008). However, little work has been conducted on local cowpea accessions in Kilifi County. The objective of this study was therefore, to determine the response of four select local vegetable cowpea accessions to cattle manure and calcium ammonium nitrate application in a sandy loam soil in coastal Kenya.

4.2 Materials and methods

4.2.1 Experimental site

The study was conducted at Kenya Agricultural Research and Livestock Organization (KALRO), Mtwapa farm in coastal Kenya. The experimental site is located at E 039° 44.680" and S 03° 54.954" in Coastal Lowland 3 agro-ecological zone (Jaetzold *et al.*, 2012). The site has sandy soils with pH of 6.9 and mean annual rainfall is 1200mm which is bimodal with the long rains starting in April running to August. Short rains begin in October and end in December. The site is at an altitude of 30m above sea level. The soil of the experimental site had low levels of nitrogen, carbon, phosphorous and potassium especially at the top soils (Table 10). Other than zinc, the other micronutrients were adequate.

Table 9: Soil analytical data for two plots used for cowpea manure and CAN application experiment at KALRO Mtwapa coastal Kenya

	Soil Analytical Data							
	Season 1 plot				Season 2 Plot			
Soil depth (cm)	Top soil		Sub-soil		Top soil		Sub soil	
Fertility result	value	Class	Value	Class	Value	class	Value	class
Soil pH	7.5	Medium alkaline	7.69	Medium alkaline	6.69	Slight acid	6.53	Slight acid
Total Nitrogen (%)	0.04	Low	0.04	Low	0.04	Low	0.03	Low
Organic Carbon %	0.38	Low	0.33	Low	0.35	Low	0.25	Low
Phosphorus (ppm)	3	Low	3	Low	15	Low	15	Low
Potassium (me %)	0.10	Low	0.64	Adequate	0.12	Low	0.40	Adequate
Calcium (me %)	2.4	Adequate	6.7	Adequate	0.8	Adequate	2.2	Adequate
Magnesium (me %)	2.06	Adequate	4.94	High	1.71	Adequate	2.51	Adequate
Manganese (me %)	0.44	Adequate	0.62	Adequate	0.27	Adequate	0.23	Adequate
Copper (ppm)	1.01	Adequate	1.09	Adequate	1.00	Adequate	1.01	Adequate
Iron (ppm)	13.0	Adequate	18.3	Adequate	18.6	Adequate	18.3	Adequate
Zinc (ppm)	4.29	Low	4.10	Low	4.81	Low	3.90	Low

Sodium (me %)	0.04	Adequate	0.54	Adequate	0.06	Adequate	0.10	adequate
Elect.Cond.(Ms/cm)	0.94	Adequate	0.96	Adequate				

The cattle manure was richer in nutrient content (Nitrogen, Potassium and Iron) and lower in Phosphorus, calcium and magnesium (Table 11).

Table 10: Cattle manure analytical data for two manures used for cowpea manure and CAN application experiment at KALRO Mtwapa coastal Kenya

Cattle manure analytical data		
Nutrient	**Cattle manure Season 1**	**Cattle manure Season 2**
Nitrogen (%)	1.40	1.05
Phosphorus (%)	0.46	0.50
Potassium (%)	0.94	1.57
Calcium (%)	1.19	1.16
Magnesium (%)	0.89	0.61
Iron (mg/kg)	1438	795
Copper (mg/kg)	14.8	13.3
Manganese (mg/kg)	484	325
Zinc (mg/kg)	103	95.5

The crop was rain-fed and the rainfall pattern was erratic for the 2 years the experiment was conducted (Table 12). January to March are normally dry and yet 150 mm of rain was recorded in January of 2012 while 260 mm was recorded in 2013 when corresponding months recorded no rain.

Table 11: Rainfall data for the period when cowpea manure and CAN application experiment were conducted at KALRO Mtwapa coastal Kenya

Month	**Rainfall**

	2012	2013
January	150.5	8.9
February	0.6	0
March	0	260.2
April	60.9	115.1
May	187.1	390.5
June	35.8	111.3
July	35.7	46.5
August	80.7	59.9
September	24	47.5
October	112.8	132.6
November	184.1	74.3
December	78.8	45.5

Source: **Mtwapa Meteorological Offices**

4.2.2 Plant material

Four high yielding and popular local cowpeas accessions, Mnyenze madamada, Sura mbaya, Katsetse and Usimpe mtu mdogo, were used in the study. Before planting was done, soil and nutrient analyses were carried out on the experimental field.

4.2.3 Experimental Design

The experiment was conducted in a randomized complete block design, and treatments arranged in a factorial manner with treatments being replicated 3 times. The accessions evaluated were Mnyenze madamanda, Sura mbaya, Katsetse and Usimpe mtu mdogo, and were planted on plots measuring 4m x 3m with plant spacing of 60 cm x 30 cm. Three rates of cattle manure (7.8, 15.6, and 23.3 tons/ha), commonly used by farmers, containing an average of 1.23% N, 0.48% P, 1.25% K, 1.16% Ca, 0.75% mg, 1116 mg/ kg Fe, 14 mg/ kg Cu, 404 mg/ kg Mn, 99.2 mg/ kg Zn was applied on the plots and thoroughly ploughed in two days before planting (Table 9). Calcium ammonium nitrate (CAN) fertilizer containing 26% N, was applied to the crop three weeks after planting as a top dress at rates of 278, 416 and 555 kg/ha. Accessions grown on soil not supplemented with any form of fertilizer acted as controls. The rates were based on quantities of containers farmers use to apply fertilizers in the region. The cowpea accessions were planted in different plots during the different seasons to avoid residual nutrient effect. The crop was rain fed and the field kept weed-free manually. Season 1 experiment was planted in June 2013 and ran up to September 2013. Season 2 trial was established in November 2013 and was concluded in January 2014.

Table 12: Factors and levels evaluated

Factor	No. levels	Levels
Cowpea accessions	4	Katsetse, Mnyenze madamada, Usimpe mtu mdogo, Sura mbaya
Cattle manure	4	0, 7.8, 15.6, 23.3 tons/ha
Calcium Ammonium Nitrate	4	0, 278, 416, 555 kg/ha
Harvesting frequency	2	Single, multiple

4.2.4 Parameters measured

The plants were established at a spacing of 60 cm x 30 cm with a plant population of 67 plants equivalent to 55,555 plants per ha. The root length, plant height, canopy width and number of branches were taken one month after planting. Six plants were sampled and average of the parameters computed. Harvesting for single harvest was done one month after planting by uprooting the whole plant. Six plants were uprooted defoliated and leaves weighed. After weighing the leaves were dried for 72 hours in an oven at 55^{o} C for determining their dry weight.

Multiple harvests started one month after planting and mature leaves from data plants were picked after every 4 days. In season 1 nine harvests were done and harvesting period extended for one month. In season 2, seven harvests were done over a period of 21 days. For dry matter determination, harvested leaves were dried in an oven for 72 hours at 55^{o} C.

4.2.5 Data analysis

Growth parameters and yield data were analysed using GenStat Statistical Programme, 14^{th} Edition (Lane and Payne, 1996**).** Mean differences among treatments were compared by Least Significant Difference (LSD) procedure at 5% level of significance.

4.3 Results

4.3.1. Effect of cattle manure and inorganic nitrogen on root length and plant height of cowpea accessions

The incorporation of various rates of cattle manure and calcium ammonium nitrate into the soils and the harvesting frequency influenced growth and fresh leaf yields of the four local cowpea accessions from Coastal part of Kenya in both seasons of the study. The root length, plant height, canopy width, branch number, single and multiple harvests of fresh and dry leaf weights were significantly affected by application of either cattle manure or calcium ammonium nitrate fertilizer (p=0.01 level of significance). The performance was also significantly affected by season of growth.

Application of different rates of cattle manure and CAN fertilizer generally caused an increase in root length of the 4 cowpea accessions in seasons 1 and 2 (Figures 4a & 4b). Usimpe mtu mdogo had consistently higher root length in both seasons, extending beyond 45 and 35 cm in season 1 and 2 respectively (Figure 4b). Mnyenze madamada had consistently lower root length than others, only extending beyond 20cm and 15cm deep in season 1 and 2 respectively. The root lengths of Katsetse and Sura Mbaya lay in between those of Usimpe mtu mdogo, and Mnyenze madamada. The response to CAN was higher than that of cattle manure with Usimpe mtu mdogo attaining over 45cm root length in season 2.

Increasing the rate of cattle manure and CAN in the soils increased plant height of all the accessions in Season 1 and 2, with magnitude of increase being higher in season 1 than in season 2. Usimpe mtu mdogo attained highest plant height at 15.6 tons/ha in both seasons. With application of CAN fertilizer, highest plant heights were recorded at the highest level of CAN application of 555 kg/ha. (Figure 5a and 5b). In both seasons highest root length was attained with application of 15.6 tons/ha of cattle manure.

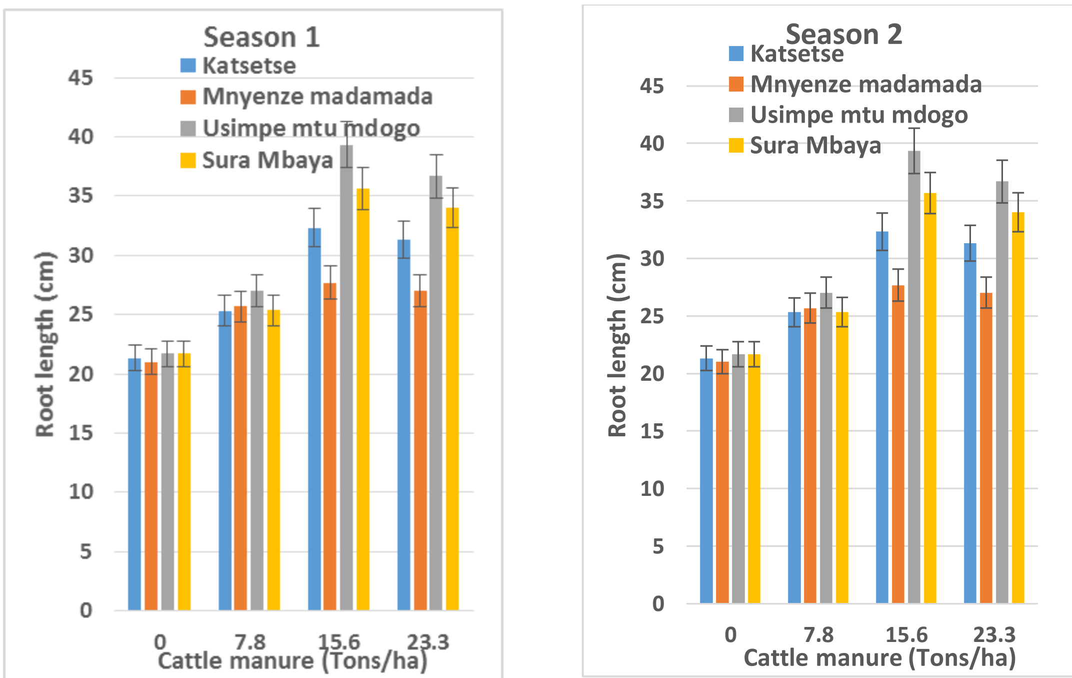

Figure 4a: Effect of cattle manure on root length (cm) of four local cowpea accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance

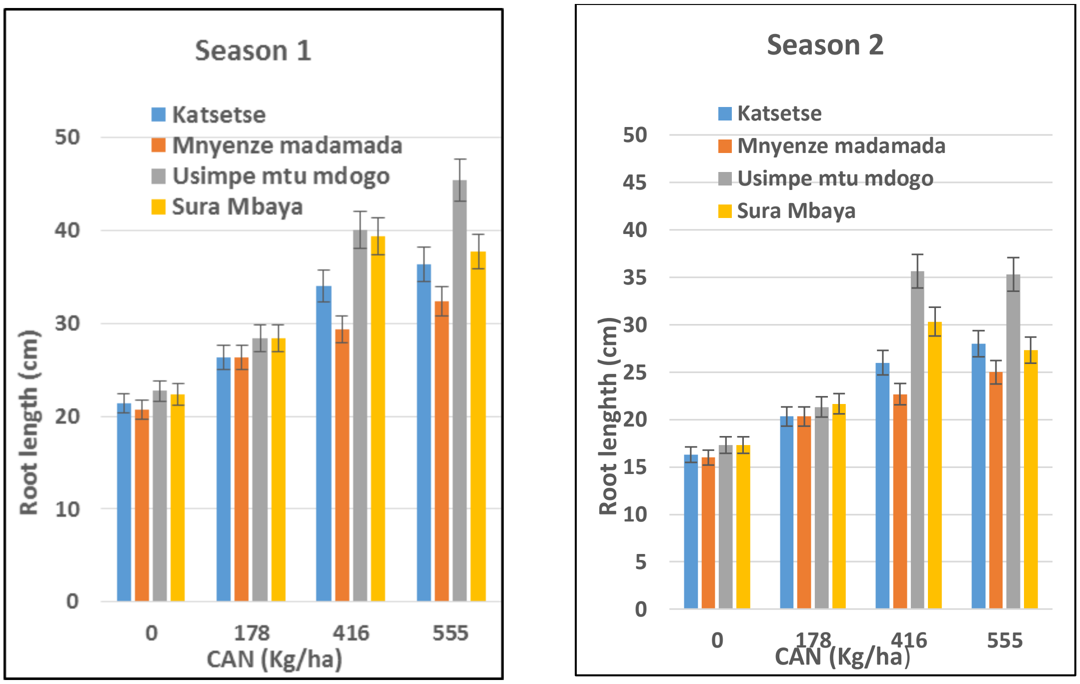

Figure 4b: Effect of calcium ammonium nitrate (CAN) on root length (cm) of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance.

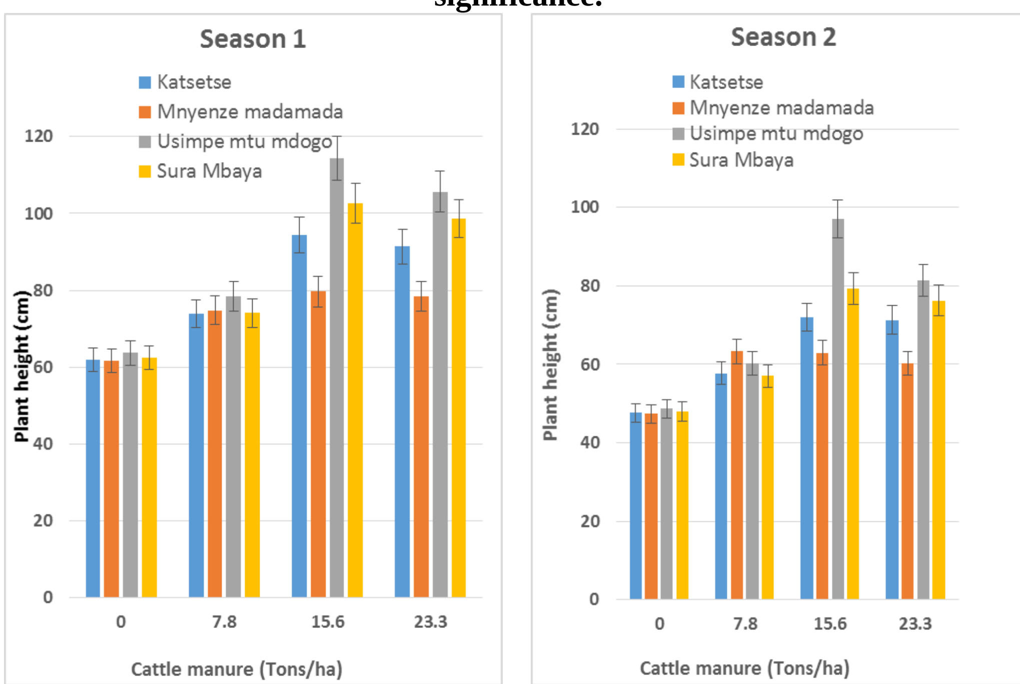

Figure 5a: Effect of cattle manure on plant height (cm) of four local cowpeas accessions in Kilifi County in Season 1. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

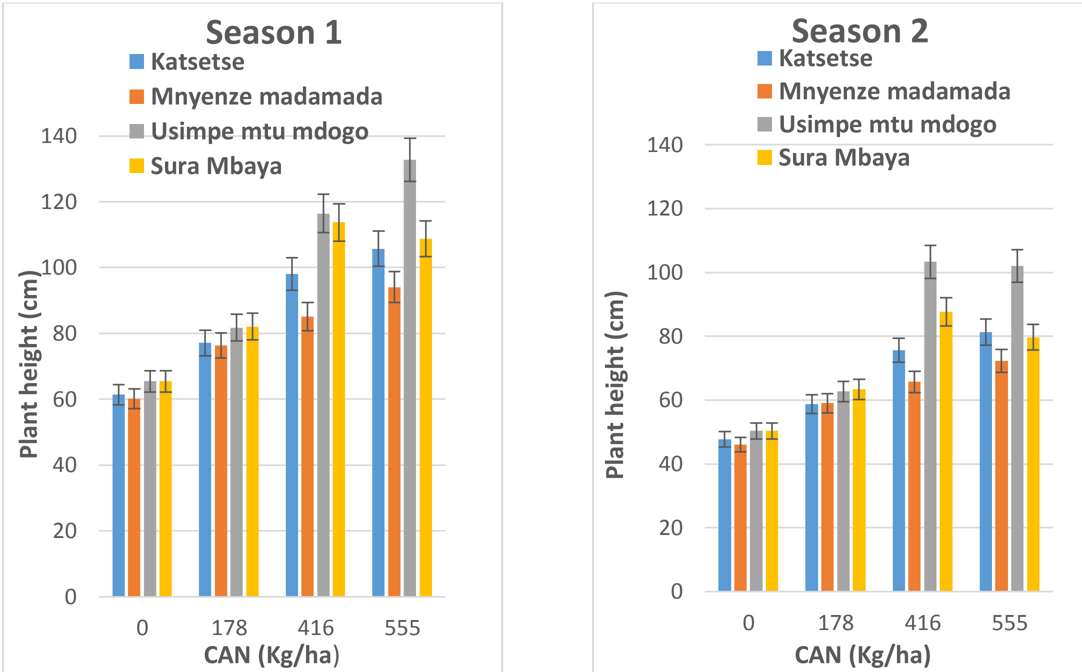

Figure 5b: Effect of calcium ammonium nitrate (CAN) on plant height (cm) of four local cowpeas accessions in Kilifi County in Season 2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

4.3.2 Effect of cattle manure and inorganic nitrogen application on canopy width of cowpea accessions

Incorporation of cattle manure and CAN fertilizer influenced canopy width of the 4 cowpeas accessions during both seasons of testing (Figures 6a & 6b). Except for the plants grown on soils supplemented with cattle manure in season 2, Usimpe mtu mdogo, Katsetse and Mnyenze madamada had wider plant canopies of up to 120 cm compared to Sura mbaya that consistently had the smallest canopy width. Treatment comparisons indicate that cattle manure was more effective in season 1 (Figure 6a), while CAN increased the canopy width of the 4 local cowpeas accessions in season 2 (Figure 6b).

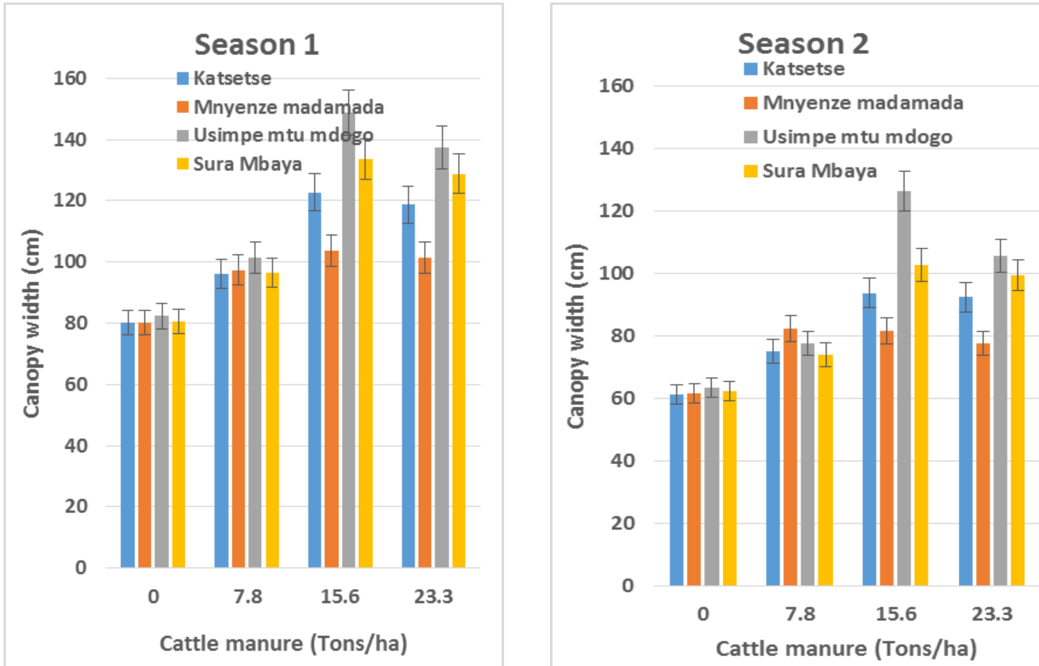

Figure 6a: Effect of cattle manure on canopy width (cm) of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

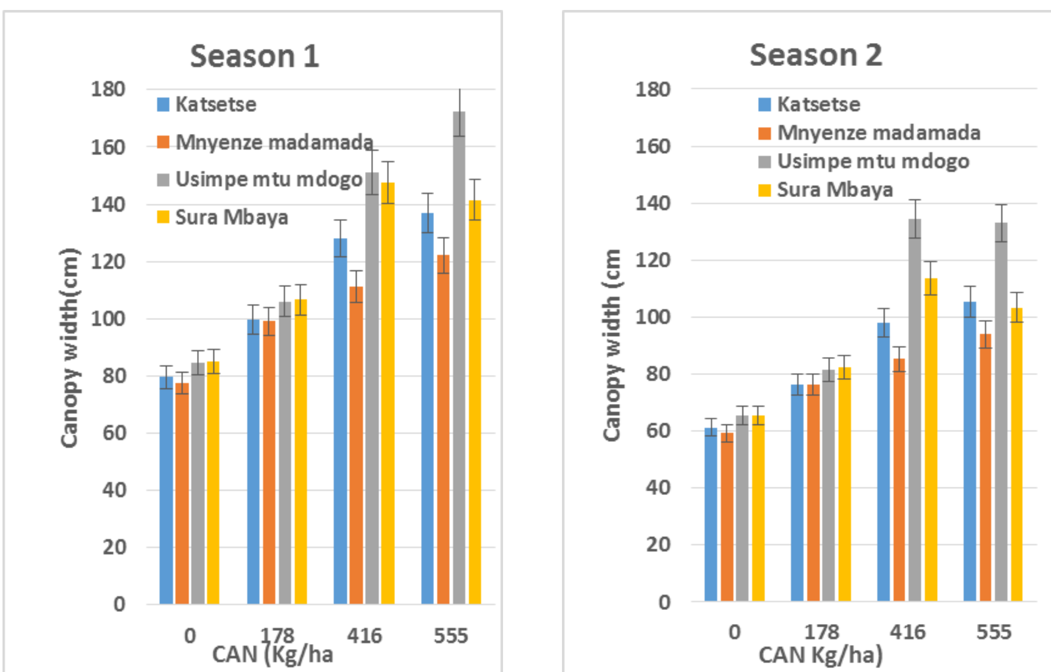

Figure 6b: Effect of Calcium ammonium nitrate (CAN) on canopy width (cm) of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

4.3.3 Effect of cattle manure and inorganic nitrogen application on number of branches

Application of manure and inorganic nitrogen had positive influence on branch number of the 4 cowpea accessions in both seasons. In season 1 Usimpe mtu mdogo and Katsetse had the highest and similar number of branches per plant of 11 with application of 15.6tons/ha of cattle manure. With application of CAN, highest number of branches (12) was attained in Katsetse at 555 kg/ha of CAN in season 1. In season to the highest branches per plant was attained by Katsetse at 555 kg/ha of CAN (Figure 7a & 7b). Application of CAN was more effective in increasing the number of branches per plant in season 1 & 2.

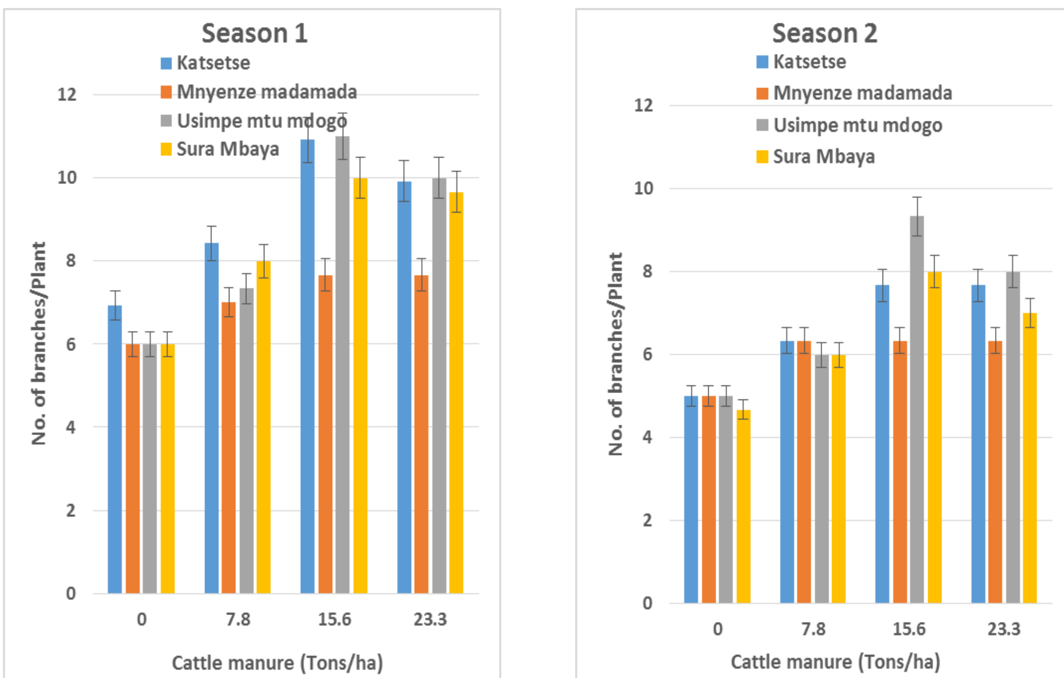

Figure 7a: Effect of cattle manure and on the number of branches/plant of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance. Means separated by LSD (P=0.05)

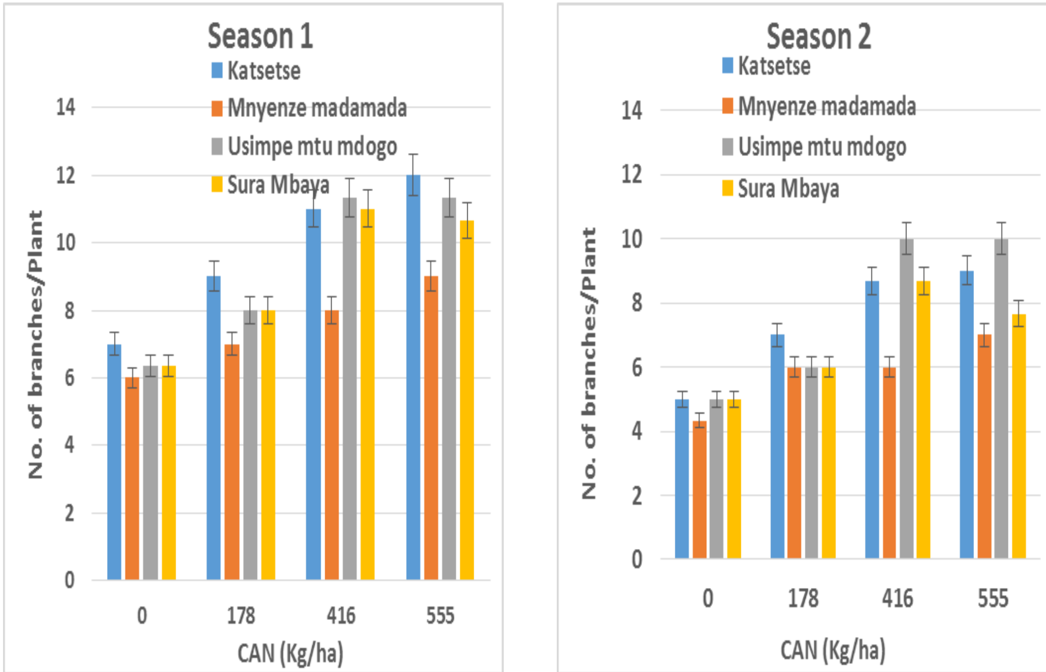

Figure 7b: Effect of Calcium ammonium nitrate (CAN) on the number of branches/plant of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance.

4.3.4 Effect of cattle manure and inorganic nitrogen on single harvest of fresh and dry leaf yields.

The fresh leaf yields harvested once in, season 1, increased with increasing levels of cattle manure application reaching maximum of 7.8 tons/ha for Usimpe mtu mdogo at application of 15.6 tons/ha from where decline was noted. In season two trend was the same but the fresh leaf yields were lower at 6.6 tons/ha for Usimpe mtu mdogo. In season 1 &2 highest leaf yields of 9 and 7 tons/ha were attained with incorporation of 555 kg/ha of CAN fertilizer in accession Usimpe mtu mdogo respectively. (Figures 8a, 8b, 9a and 9b). Accession Usimpe mtu mdogo and Sura mbaya at 15.6 tons/ ha and 555 kg/ha CAN recorded highest leaf yields. Leaf yields were lower in season 2 than season 1. The dry leaf yields followed a similar trend with dry leaf yields with Usimpe mtu mdogo yielding 2.8 tons/ha of dry leaf in season 1and 2.4 tons in season 2.4.

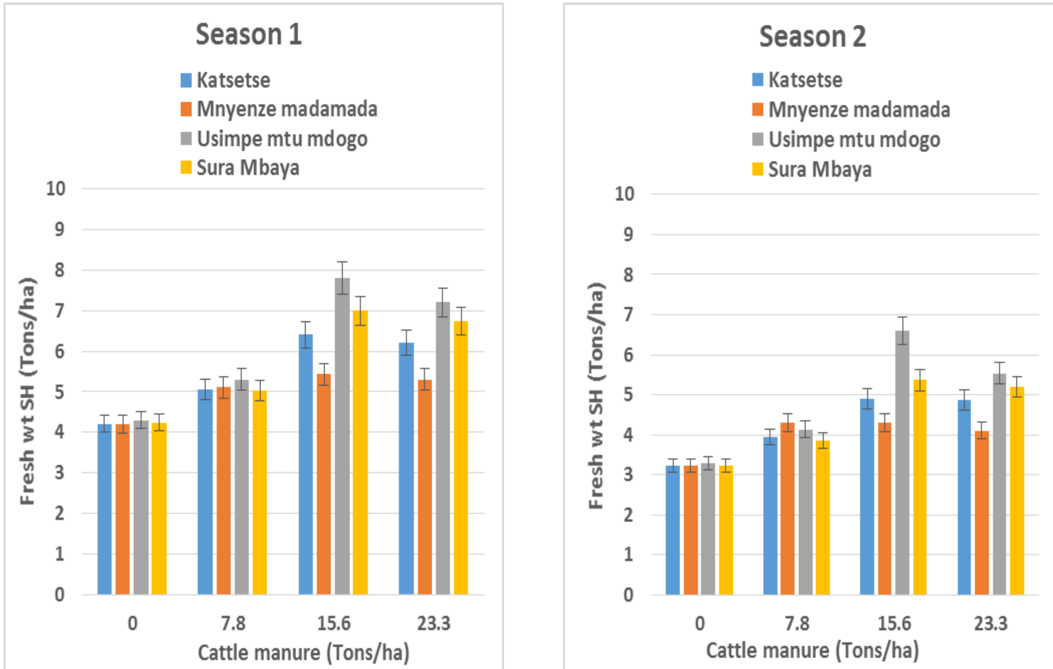

Figure 8a: Effect of cattle manure on Fresh weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

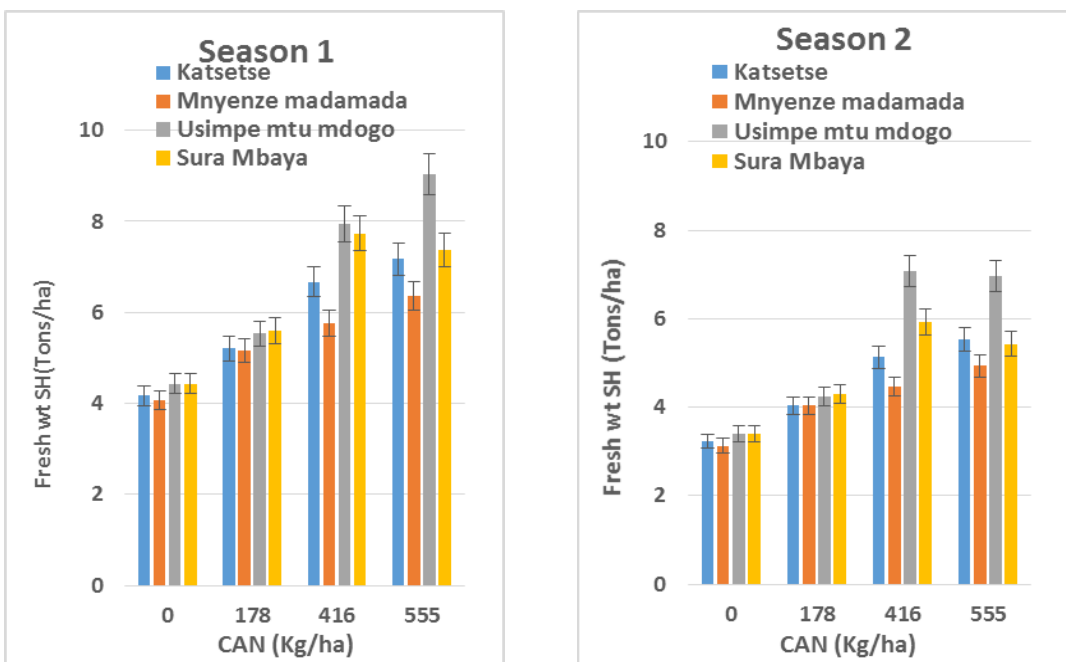

Figure 8b: Effect of Calcium ammonium nitrate (CAN) on Fresh weight (tons/ha) of single harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

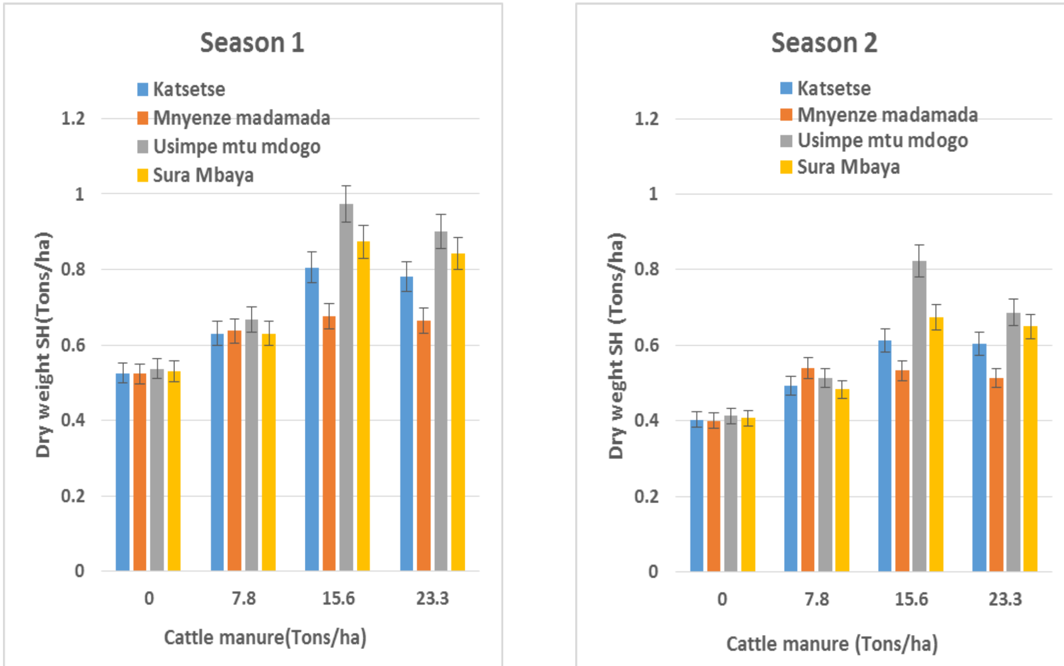

Figure 9a: Effect of cattle manure on dry weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

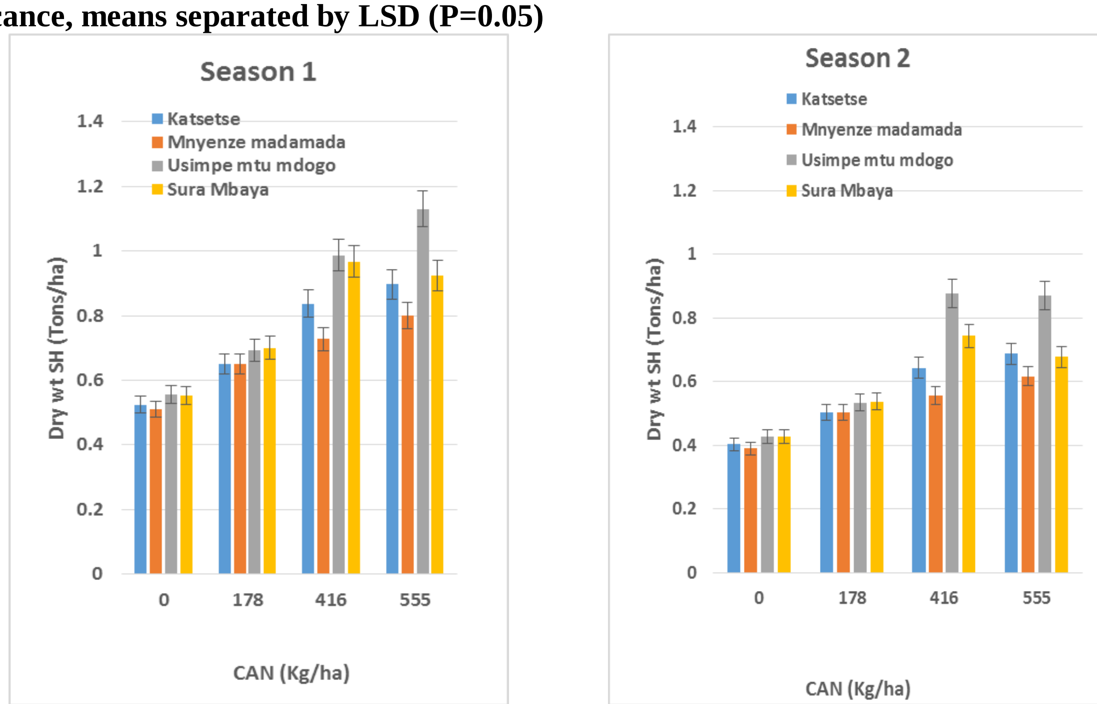

Figure 9b: Effect of Calcium ammonium nitrate (CAN) on dry weight (tons/ha) of single harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

4.3.5 Effect of cattle manure and inorganic nitrogen on multiple harvests of fresh and dry leaf yields

Multiple harvesting of cowpea resulted in a large increase in the fresh yields (Figures 10a & 10b) as compared to single harvest (Figures 8a and 8b). The best yields of 27.4 tons/ha of fresh leaves, were achieved in accession Usimpe mtu mdogo with application of CAN fertilizer at rates of 555kg/ha. Sura Mbaya was second with leaf yields of 22.4 tons/ha. Least leaf yields were observed in accession Mnyenze madamada while Katsetse fell slightly above Mnyenze madamada. The accessions responded differently to CAN fertilizer application. Sura Mbaya performed best at the lower rate of 416 kg CAN/ha. Incorporation of manure 15.6 tons of manure in the soil resulted in best leaf yields of 23.6 tons/ha in Usimpe mtu mdogo. The accession Usimpe Mtu mdogo had highest leaf yields in both seasons. The yields were lower in second season. The lower rainfall and higher temperatures experienced in November to December could have contributed to lower leaf yields in the second season. Dry leaf weights of multiple harvests differed with accession although the highest weights were recorded with application of 555kgCAN/ha (Figure 11a & 11b). Accession Katsetse had highest dry leaf yields of 3.1 tons/ha ha and was followed by Usimpe mtu mdogo which yielded 2.9 tons/ha dry leaf yields with application of 555kg CAN/ha. With incorporation of cattle manure, Usimpe mtu mdogo had the highest dry leaf weights of 2.8tons/ha at 15.6 tons manure per ha. Similar trend was observed in second season although yields were lower. In the second season highest dry leaf weights of 2.5 tons/ha were recorded in Usimpe mtu mdogo with application of 555kg CAN/ha. Katsetse followed with dry weights of 2.3 tons per ha. Lowest performance was observed in accession Mnyenze which had consistently lower dry leaf yields with application of the nitrogenous fertilizer.

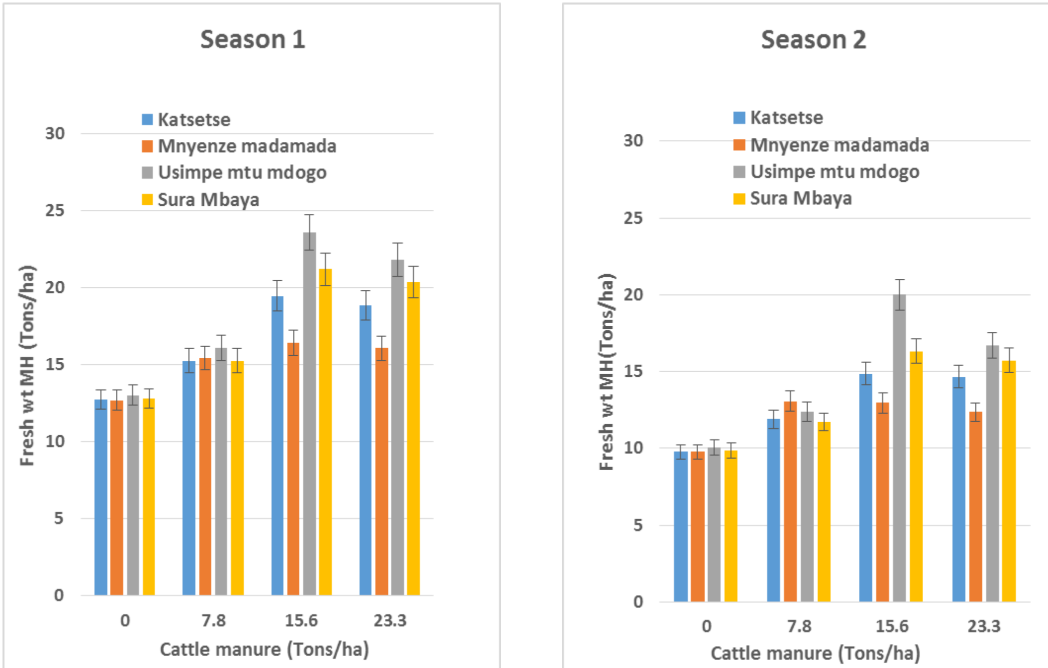

Figure 10a: Effect of cattle manure on fresh weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance. Means separated by LSD (P=0.05)

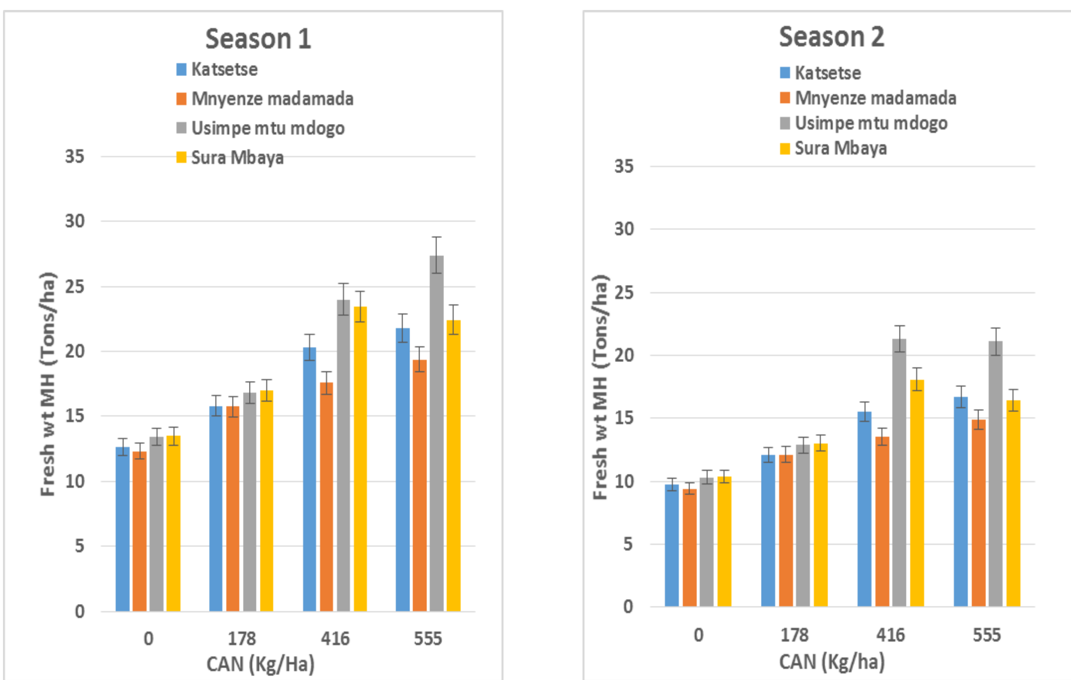

Figure 10b: Effect of CAN on fresh weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance. Means separated by LSD (P=0.05)

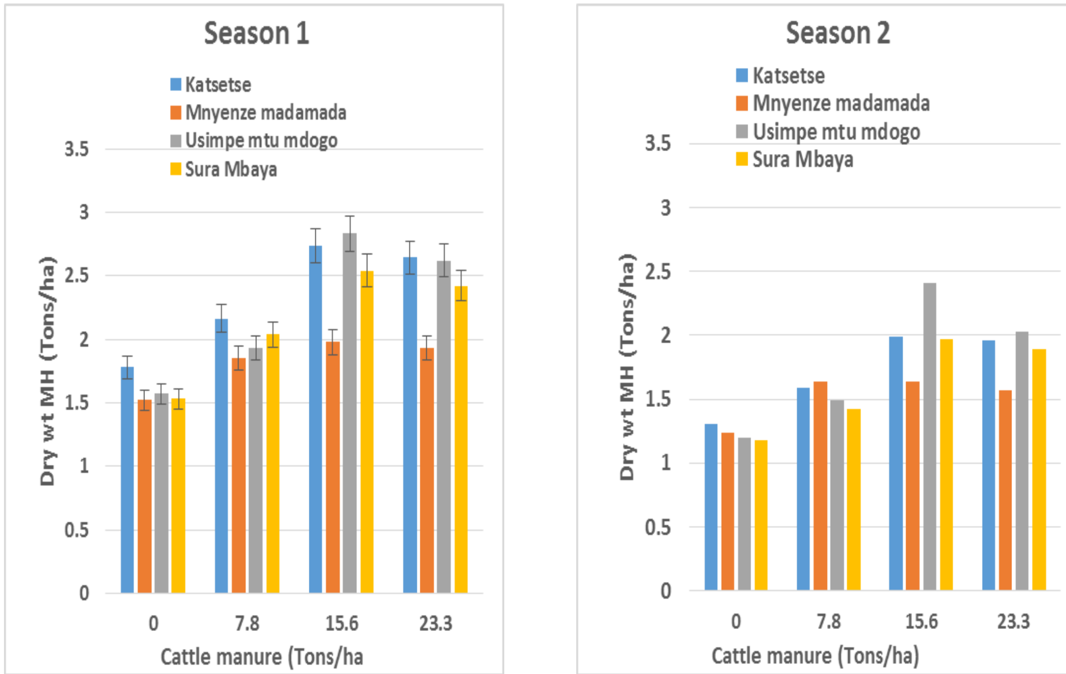

Figure 11a: Effect of cattle manure on dry weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance. Means separated by LSD (P=0.05)

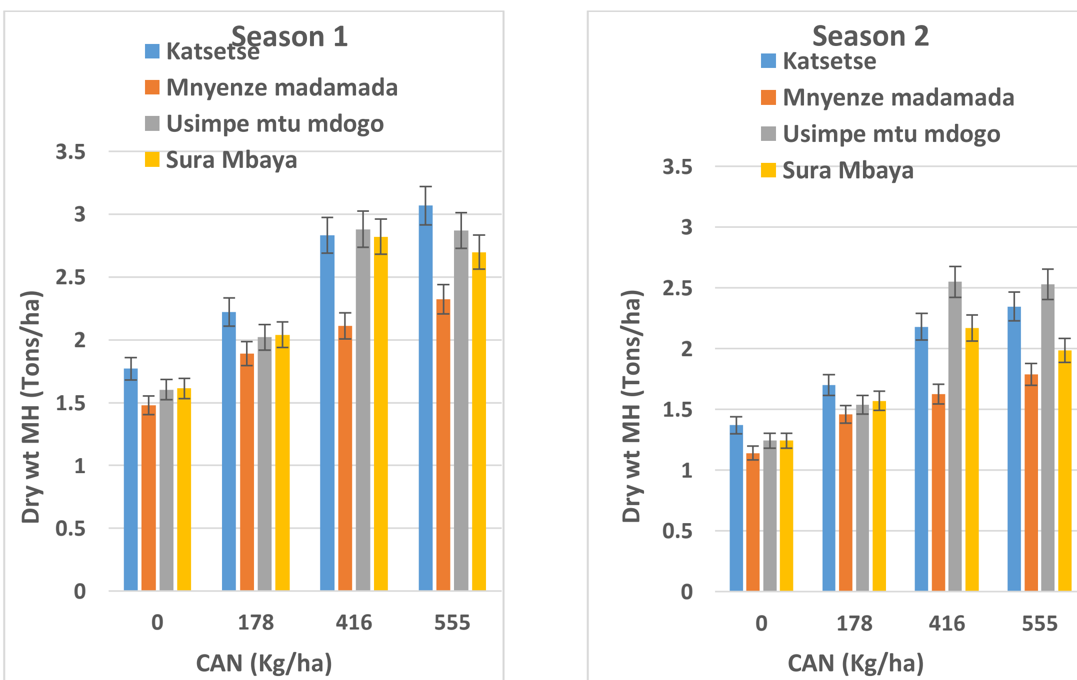

Figure 11b: Effect of CAN on dry weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi County in Season 1&2. Bars represent error at 5% level of significance, means separated by LSD (P=0.05)

4.4 Discussion

Although local germplasm are often more popular than exotics in rural communities, their yields are often low and below genetic potential especially when grown in poor and infertile soils. The uptake of improved technologies has been shown to improve yields of many crops. Application of either manures alone or Nitrogen fertilizers is known to increase yields through supporting plant vegetative growth with consequence increase in yields of crops (Nyle *et al*., 2002.). For vegetable cowpea whose harvestable portion is the leaf, nitrogen is a very critical nutrient for abundant leaf production. Animal manures are very important in crop production. They release their contents slowly ensuring an extended supply of nutrients to the plant. They help improve the soil physical properties hence the corresponding increase in water infiltration. They also help in increasing moisture ability of the soils to retain moisture. Additionally through increasing the soil organic matter, they help in balancing the soils pH as a result of improved soils' buffering capacity. The present study results indicate that the application of organic manure and inorganic fertilizer influenced growth, development and leaf yields of the local cowpea accessions in Kilifi. Higher concentrations of CAN suppressed root growth for Usimpe mtu mdogo and Sura mbaya accessions. Usimpe mtu mdogo grown on soils complemented with cattle manure produced the longest roots in season 1 compared to Katsetse in season 2. This indicates that different accessions respond differently to fertilizer N application and manure applications. Choice of accession is therefore an important consideration when applying nutrients for increasing productivity.

Similar trends have been reported in Morogoro, Tanzania where application of 8t/ha of both poultry and goat manures increased the height of cowpeas (Kisetu and Assenga, 2013). Another study in Sri Lanka showed that high cowpeas leaf yields were obtained through application of chicken manure combined with the recommended rate of inorganic fertilizer (Yoganathan *et al*., 2013) although goat and cattle manure were not as good as chicken manure.

Animal manure is a good source of organic matter in the soil and helps to improve chemical, physical and biological properties of the soil and is also a source of energy in the soil ecosystem. Using manures in cowpea production can increase yields through increased water holding capacity of the soil and improved cation exchange capacity (Nandwa, 1995). Through improving nitrogen and other nutrients in the soil, they can enhance crop production. Nutrition of vegetables such as cowpeas is characterized by shallow root system and fast growth rate. Fast growth rates call for sufficient supply of nutrients throughout the growth period as observed in another African leafy vegetable, *Cleome gynandra* (Hutchinson *et al*., 2006). Current consumer demand is for organically grown products since they are presumed to toxic residue free and have concern for health environment. This study indicates that depending on the season, cattle manure can promote higher yields than inorganic fertilizer. It is however important to note that cowpea may not require a lot of nitrogen fertilizer because it has ability to fix own nitrogen through nodules in its roots. In contrast Kouyaté *et al.,* (2012) working on cowpea in Mali reported a low response to organic matter and higher nodulation with corresponding higher nitrogen fixation. However Kombiok *et al.*, (2005) found that cropping systems in Ghana had no effect on nodule number and nodule weight.

Some commercial farmers often harvest their cowpea once by uprooting the entire crop. The results from the present study indicate that multiple harvests increase cumulative yields and improve general plant growth and development. In a study conducted in Swaziland where the effects of nitrogen application and leaf harvesting frequency were investigated, it was found that additional nitrogen increased seed yield (Dlamini and Edje, 1999). The seasonal fluctuations on yield suggest the need to investigate optional management practices to enhance incomes and cowpea availability throughout the year.

4.5 Conclusion

The results of this study show that incorporation of 15.6 tons of cattle manure and 555kg/ha of Calcium ammonium nitrate (26%N) fertilizer was optimal for cowpea leaf production in coastal lowland 4 agro-ecological zone in coastal Kenya. The accession Usimpe mtu mdogo performed best in fresh leaf yield production during the two seasons of testing showing it was the most adapted accession in the collection. Sequential leaf harvesting system was more productive as compared single harvest system achieved through uprooting the whole plant four weeks after planting. Use of organic and inorganic soil amendments were shown to improve leaf productivity substantially when compared with no amendment application in the control plots. Organic manure which are available in them farm especially where famer keep chicken goats or cattle could provide a suitable alternative of resource poor farmers in the coastal region.

CHAPTER FIVE

5. GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

From the accession collection mission, it is clearly evident there exists is a large number of cowpea accessions cultivated and utilized as vegetables in Kilifi and Mombasa counties for subsistence and commercial purposes. The accessions vary in morphological and agronomic characteristics. The study identified the accessions preferred by farmers among those that performed best in leaf yield production. To improve the production and commercialize the preferred accession such as Mnyenze madamanda, Sura mbaya, and Katsetse and Usimpe mtu mdogo, there is need to establish a seed multiplication programme. This will avail suitable planting materials of vegetable cowpea varieties.

5.2 Conclusions

1. Principal component analysis showed that morphological variation among the cowpea accessions evaluated does not exist, which means the good traits for instance drought resistant are still retained within the accessions. Mnyenze madamada, Sura mbaya, Katsetse and Usimpe mtu mdogo were identified as most suitable accessions through variety evaluation and farmer selection.

2. Cowpea accessions responded to application of cattle manure and calcium ammonium nitrate fertilizer with incorporation of about 15.6 tons/ha of cattle manure and 555 kg/ha CAN being optimal for improved growth and leaf yield production in four cowpea accessions in coastal Kenya.

5.3.1 Recommendations

1. From the results of this work, accession Usimpe mtu mdogo, Sura mbaya, Mnyenze madamada and Katsetse are recommended for cultivation as vegetable cowpea in coastal Kenya.

2. Leaf nutrition analysis should be conducted to document the nutrient composition of cowpea accessions

3. Molecular characterization of the accessions should be conducted.

4. Farmers should adopt more mixed systems so that cowpea production using organic manure can be more sustainable for commercialization.

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APPENDICES

Appendix 1: Mean squares for root length, plant height, canopy width and number of branches of four cowpea accessions evaluated at KALRO Mtwapa

Source of variation	Degrees of freedom	Root length	Plant height	Canopy width	Number of branches
Season	1	2034.5**	17063**	28959.2**	161.3**
Treatment	7	766.6**	6426.9**	10940.9**	60.0**
Accessions	3	304.4**	2570.8**	4382.5**	21.1**
Treatment x Accession	21	34.1**	293.7**	500.7**	2.5**
Residue	159	2.97	24.95	42.56**	0.49
Total	191				

NB*, ** = Significant difference at 0.05 and 0.01 levels.

Appendix 2: Mean squares for single harvest leaf fresh weight, single harvest dry leaf weight, multiple harvest leaf fresh weight and multiple harvest leaf dry weight of four cowpea accessions evaluated at KALRO Mtwapa

Source of variation	Degrees of freedom	single harvest fresh weight	single harvest dry leaf weight	multiple harvest leaf fresh weight	multiple harvest leaf dry weight
Season	1	82.2**	1.24**	729.3**	11.0**
Treatment	7	31.6**	0.46**	275.4**	4.0**
Accessions	3	12.3**	0.18**	109.7**	1.6**
Treatment x Accession	21	1.6**	0.02**	12.7**	0.15**
Residue	159	0.03	0.001	1.07	0.027
Total	191				

NB*, ** = Significant difference at 0.05 and 0.01 levels