QUALITY OF COWPEA SEED USED BY FARMERS IN MAKUENI AND TAITA TAVETA COUNTIES AND ITS EFFECT ON CROP PERFORMANCE

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DECLARATION

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

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DEDICATION

I dedicate this work to my loving mother Mrs. Jane Mumbi, father Mr. Charles Njonjo and my dearest siblings Wairimu Njonjo and Waweru Njonjo and to my very supportive and caring husband Mr. Ng'ang'a Karue.

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ABBREVIATIONS AND ACRONYMS

AATF	Africa Agricultural Technology Transfer
ASALS	Arid and Semi- Arid Lands
BICMV	Black-eye Cowpea Mosaic Potyvirus
C	Celsius
CABMV	Cowpea Aphid Borne Mosaic Virus
CBO	Community Based Organization
CMV	Cucumber Mosaic Cucumovirus
CPMoV	Cowpea Mottle Carmovirus
CPMV	Cowpea Mosaic Virus
CPSMV	Cowpea Severe Mosaic Comovirus
CRS	Catholic Relief Services
CV	Co-efficient of Variance
DLSC	Dry Land Seed Company
DNA	Double Nucleic Acid
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GOK	Government of Kenya
Ha	Hectares
ICARDA	International Centre for Agricultural Research for Dry areas
IITA	International Institute for Tropical Agriculture
ISTA	International Seed Testing Association
K80	Katumani 80
KALRO	Kenya Agriculture, Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Services
Kg	Kilogram
LM4	Lower Midland IV

LM5	Lower Midland V
LSD	Least Significant Difference
M66	Machakos 66
MoALF	Ministry of Agriculture Livestock and Fisheries
N	Nitrogen
NGICA	Network for Genetic Improvement of Cowpea in Africa
NGO	Non-Governmental Organization
NSCAA	Nutrient Starch Cyclo-heximide Antibiotic Agar
P	Phosphorous
PAS-ELISA	Protein Sandwich Enzyme Linked Immunosorbent Assays
PCR	Polymerase Chain Reaction
PV	Pathovar
RCBD	Randomized Complete Block Design
RNA	Ribonucleic Acid
SBMV	Southern Bean Mosaic Sobemovirus
SPSS	Social Package for Social Statistics
USA	United States of America
USAID	United States Agency for International Development

GENERAL ABSTRACT

It is estimated that 80% of the farmers in Africa use seeds from the informal seed system that are of unknown quality. Contamination of such seeds with impurities and disease causing pathogens is common leading to reduced establishment in the field, high incidences of seed borne diseases and reduced crop establishment. An understanding of the status of the cowpea seeds used by farmers will be vital in giving appropriate recommendation to cowpea farmers on how cowpea productivity can be improved. This study was conducted to assess cowpea production practices, purity and physiological quality of the seeds and the effect of the seed source on the grain yield.

A survey was conducted in Makueni and Taita Taveta counties by administering a semi-structured questionnaire to 114 farmers selected by purposive sampling. Information was collected on seed used, seed sources, varieties grown, number of seasons the seed is recycled, acreage under cowpea, cropping systems, production trend of yields in 2015 and 2016, methods of harvesting and post-harvest handling practices of cowpea seed. From each farmer 500g of cowpea seed samples were collected and in addition 34 samples were collected from local markets within areas of study. The seeds were analysed for purity, germination and seedling vigour following ISTA procedures. Purity was by separating each of the four replicates each of 100g of the seed samples into pure seed, other crop seeds, discoloured and shrivelled seeds, weed seeds and inert matter. Germination was assessed by planting four replicates each of a 100 seeds on paper towel and the number of germinated seeds, normal seedlings, mouldy seeds and infected seedlings counted while seedling vigour index was obtained via measuring the dry weight of the seedlings as well as measuring the seedling length. Three varieties of cowpea seed (KVU, K80, and M66) from farm, market and certified sources were planted in RCBD design in split plot layout in two sites at Kambi Ya Mawe (LM4) and Kiboko (LM5) during 2016 short rains. The data collected included emergence, plant stand, disease incidence and severity, yield and yield components which were pods per plant, seeds per pod, 1000 seed weight, grain yield and dry matter yield.

Majority of the farmers (64%) were using farm saved uncertified seeds at up to 82%. Physical purity levels of all seeds samples from markets and farmers were below the recommended 98.0% while only farm saved from Mwatate met the recommended 75% germination. There was no significant difference in the germination of the five varieties tested and none attained the recommended rate of 75%. Farm saved seeds had the highest mean vigour index with the seeds from Mwatate being the highest and significantly different from the one from the other two areas.

Certified and market sourced seed had the highest seedling emergence at up to 79% and 80% respectively. Farm saved seeds had the highest percentage of rotten seeds at up to 35% which was significantly different from the other two seed sources. Certified and market sourced seeds had the highest plant stand compared to farm saved seeds with over 58% and 20% at Kambi Ya Mawe and Kiboko site respectively. Bacterial blight incidence and severity was not significantly different between the seed sources while the dry grain and dry matter yield was highest in certified seeds. The seeds per pod and pod length were not affected by the seed source.

It was therefore concluded that the cowpea seeds used by farmers do not meet the set thresholds of cowpea seed quality and therefore they are not recommendable for use if farmers are to achieve high yields from the crop.

Key words: Cowpea, seed quality, seed system, seed source, variety performance.

CHAPTER ONE: INTRODUCTION

1.1Background information

Agriculture sector is the backbone of Kenya's economy and a source of livelihood of high population that are in the rural areas. It contributes about 26% to the GDP and directly or indirectly employs over 75% of the entire population. The sector is a major source of revenue accrued to the export of agricultural produce which accounts for more than two thirds of the total domestic export and hence its support is counted on for securing a high percentage of the total Kenya's population (MoALF, 2015).

Economic growth is one of the pillars of Vision 2030 and at the onset of this strategy the aim was to increase GDP by 10% annually. The GDP growth rate was not achieved in the medium term plan one 2008-2012 as expected as it was at 6%. In the medium term plan two 2013-2017 agriculture sector has still been identified as one of the major sectors which will help to deliver the 10% annual GDP growth rate and will also participate in the reduction of poverty levels in the country. The focus will be on making the arid and semi-arid areas productive agriculturally through irrigation while still putting into consideration mechanisms to cope with climate change (GOK. 2008, World Bank, 2014).

Worldwide cowpea production is estimated to be at 6.5million metric tonnes annually on about 14.5million acres. Out of the total world production, Africa produces over 83% with 80% of it being from West Africa. Nigeria is the world's leading consumer and producer at 45% followed by Niger (15%), Brazil (12%), and Burkina Faso (5%) (Fatokun *et al*., 2012b). It is considered the most important legume in the dry savannah of the tropical Africa with high energy levels almost equal to that of cereals (AATF/NGICA, 2006). Low yields are significant attribute of production estimates, particularly in Africa where 240-300kg /ha are often realized. The reasons include biotic factors- particularly from insects and other pests, which often affect the plant throughout the crop season and also seeds in storage. Quite a number of insects attack cowpea (Kimiti *et al.*, 2009).

In Kenya, cowpea is widely produced for its leaves in Western Kenya while for its grain it is produced in Eastern, Coast and Nyanza regions (Rusike *et al.,* 2013). In 2012, Eastern Kenya produced 90% of the total national output with Kitui, Makueni and Machakos counties leading in terms of production. Nationally, it is grown on 214,492ha with 187,910ha in Eastern Province (MoALF, 2015).

In 2011, there was an increase in area under production and total output with 18% and 13% respectively compared to 2010 the increase could be attributed to increase in area under production as well as the ministry having availed seeds on time. There has been an increase in the cowpea production from 133,756 tons in 2013 to 138,673 tons in 2014 with the area under cowpea increasing from 250,798 ha in 2013 to 281,877 ha in 2014. This has been attributed to the campaign by the ministry of agriculture and other partners on the need to adopt drought tolerant crops. However, a decrease in production per hectare was recorded from 531 kg/ha in 2013 to 495 kg/ha in 2014 (MoALF, 2015).

Cowpea's high protein content, adaptability to different types of soils and intercropping systems, resistance to drought, ability to improve soil fertility and prevent soil erosion makes it economically important in many developing countries (Hall *et al*., 2002; Hall, 2004).

Table1.1 : Annual production cowpeas in Kenya between years 2010 to 2014

Year	2010	2011	2012	2013	2014
Area(ha)	168,273	197,980	215,269	250,798	281,877
Production 90 kg bags	803,046	905,938	1,266,238	1,486,180	1,540,813
Tons	72,274	81,534	113,961	133,756	138,673
Yield (kg/ha)	405	414	531	531	495
Consumption(e)	..	650,000	1,066,667	…	…
Price/ 90 kg bag(Ksh)	…	3,934	6,220	…	…
Total value (Billion Ksh.)	…	3.6	7.9		

Source: MoALF e= Estimated value..=data not available …= data not available yet

Cowpea is a dual-purpose crop used as a vegetable and a seed crop. The semi-spread varieties are suitable for vegetables, which are harvested by uprooting when still green at the seedling, stage (Karanja *et al*., 2008). It is used as a vegetable due to its palatability, high nutrition and relatively free of metabolites or other toxicants (Bubenheim *et al*., 1990; Hutchinson *et al*., 2016).

The seed act as an inexpensive rich source of protein. This is primarily used in form of dry seed cooked as a pulse in a large variety of dishes (Timko and Singh, 2008). It is nutritious, highly palatable and relatively free from metabolites and toxins hence provide an inexpensive source of protein (Aveling, 2007). It also has vitamins and minerals as well as folic acid and vitamin B than other plants that are essential during pregnancy as they help prevent defects in the brain and the spinal cord of the child (Hall *et al*, 2002; Timko and Singh, 2008).

Cowpea is usually grown as an intercrop with sorghum, maize and millet (Asiewe, 2009). However, intercropping with roots and tuber crops is discouraged since it appears to favour the build-up of nematodes. Short season varieties (60-65 days) are sometimes grown in a monoculture system or a late relay crop in sorghum or maize to use residual moisture in the soil (Rachie, 1981).

Table 1.2: Percentage chemical composition of the various components of cowpea

	Seed	Leaves	Hay
Carbohydrates	56.0-66.0	8.0	0.0
Protein	22.0-24.0	4.7	0.0
Water	11.0	85.0	18.0
Crude fibre	5.9-7.3	2.0	9.6
Ash	3.4-3.9	0.0	23.3
Fat	1.3-1.5	0.3	11.3
Phosphorous	0.1	0.1	2.6
Calcium	0.1	0.3	0.0
Iron	0.0	0.0	0.0

Source: Kay, 1979, Tindall,1983, Quass, 1995

1.2 Problem statement

Cowpea is an important legume majorly grown by resource-constrained farmers in Sub Saharan Africa who lack resources to buy certified seeds during the planting season (Okeyo-Ikawa *et al*., 2016). Certified seeds available in the market are also not easily accessible by farmers in interior areas as private seed companies are profit oriented are unwilling to supply small quantities of seed over long distances (Almekinders and Louwaars, 2002; Kimani *et al.*, 2014) yet informal seeds are always available at the market when required (Salifou *et al*., 2017).

Certified seeds are relatively costly compared to the grain legume and farmers are unwilling to buy certified seeds at a cost twice the cost of grain (Sperling *et al*., 2004; Rubyogo *et al*., 2007). Cowpea farmers also have a high preference for local landraces due to their palatability despite their low yields compared to improved varieties (Hutchinson *et al.*, 2016). Cowpea farmers are faced with a wide range of challenges that among them are shortage of seed supply during the planting time, inadequate farm inputs, pests and diseases as well as weed infestation (Kimiti *et al*., 2009). These farmers resolve to using seeds from the informal seed system either as own saved seeds, from the market and from the neighbours, which are of unknown quality.

Seed from informal system are characterized with varietal mixtures or land races as they are often selected from the grains using various criteria such as grain size, colour and yield potential among others (Orawu, 2007). The processing, handling and storage of these seeds is often under suboptimal conditions resulting in seed damage especially by storage pests such as bruchids, which results to loss of seed viability. These seeds are also subjected to recycling over many years resulting to low yields due to insect pest damage and accumulation of seed borne pathogens of bacterial, fungal and viral nature that affects seed productivity adversely (Muthamia and Kanampiu, 1996; Matikiti *et al*., 2012; Kimiywe, 2015).

Seed recycling over long period also results to loss of quality of seed and subsequently poor yields (Amaza *et al*., 2010). Farmers using seed of unknown quality risk low emergence as well as low plant vigour that eventually result to poor physiological quality (Matthews *et al*., 2012). Use of seeds of poor health leads to low germination percentage, seedling mortality, stunted growth and eventually low yields (Solorzano and Malvick, 2011).

1.3 Justification

Use of quality seed is the most important input since subsequent practices after planting depend on the quality of seed planted (Copeland and MacDonald, 2001). However, access to quality seed remains a challenge in Sub Saharan Africa due to the under developed seed system comprising of over 80% of seeds from the informal seeds system resulting to low crop productivity (Louwaars, 2007; Mohammed, 2013). According to ISTA, 2015, quality aspects of seed include purity, germination, vigour, genetic purity and seed health. High physical quality is crucial in establishing adequate plant stand that directly affects yield (McGuire, 2005).

The vigour of seed is what defines the ability of seed to germinate into established seedlings uniformly across various environmental conditions (Finch-Savage, 2016). Problems from the informal seeds are attributed to sub-optimal seed production, selection and storage practices. These suboptimal practices can affect all aspects of seed quality such as genetic purity, physiological quality, seed health and purity (Almekinders, 2000).

In Kenya over the last five years there has been an increase in the area under the cultivation of cowpea however the production in kilograms per hectares has decreased from 531 kg/ha in 2013 to 513Kg /ha in 2014 (MoALF, 2015). Despite the release of more than 10 varieties of cowpea between 1997 and 2010, only about 10% of cowpea farmers use certified seeds (Rusike *et al*., 2013). Therefore, the majority of the farmers use farm saved seeds, from other farmers and others buy from the local markets during the planting season. These seeds are of unknown quality and origin hence is likely to be the cause of reduction in yields (GOK, 2006).

Additional constraints in cowpea production is seed which is attributed to issues such as seed production and availability, seed access distribution as well as seed quality (Majiwa *et al*., 2004). Studies regarding production practices and the cowpea seed quality used by farmers from the informal seed systems have not yet been conducted locally. The effect of seed quality on crop performance has not been studied. Therefore the need to carry out a research to determine the production practices, quality of cowpea seed used by farmers and its effect on cowpea yield and components of yield.

1.4 Objectives

The broad objective was to determine quality of farm saved seed in Makueni and Taita Taveta Counties and its effect on grain yield for improved productivity.

The specific objectives were:

(i) To determine the cowpea seed production practices and physiological quality of seed used by farmers in Makueni and Taita Taveta counties in Eastern and Coastal regions of Kenya.

(ii) To determine the effect of quality of seed cowpea seed on dry grain yield.

1.5 Hypothesis

(i) Cowpea seed production practices and post-harvest handling have effect on purity and physiological quality of seed

(ii) Seed source has effect on quality of seed and dry grain yield

CHAPTER TWO: LITERATURE REVIEW

2.1 Cowpea production in Kenya

Africa contribute 92% of all cowpea consumed globally by approximately 200 million people daily (Popelka *et al*., 2004). The leading producer and consumer of cowpea globally is Nigeria with an approximately 2.4million tonnes annual production produced on five million hectares, closely followed by Niger, Brazil and U.S.A (USAID, 2010).

In Kenya cowpea production is characterized by extremely low yield with a range of 102-239 kg/ha compared to potential yields of 1200-1800 kg/ha as reported by Kimiti *et al*., 2009. Cowpea is the third most important grain legume after beans and pigeon peas although the two are not tolerant to adverse growing conditions as cowpeas (Kimiti *et al*., 2009; Kimani *et al*., 2014). It is recommended for ASALS and also for medium and high altitudes of between 1200-1500m above the sea level in Agro-ecological zones, III and IV as opposed to high potential areas (AATF/NGICA, 2006). Approximately 85% of total area under cowpeas is in the arid and semi-arid lands (ASALS) of Eastern region and 15% in the Coast, Western and Central regions of Kenya (Muthamia and Kanampiu, 1996; Muli and Saha, 2000).

Varieties M66, KVU and K80 are dual-purpose varieties suitable for dry areas of Kenya mainly the Eastern and Coastal regions as recommended by Kenya Agricultural Livestock Research Organization (Karanja *et al*., 2008). Preference for the dual-purpose varieties is because they offer versatility in use for use of leaves and seeds from the same crop (Bubenheim *et al*., 1990). The varieties vary in seed size, shape and colour, maturity time, leaves size and shape, growth habit and height. Colour is the main factor distinguishing between varieties during marketing since each of the grain colours has its own market niche and price (Karanja *et al*., 2014).

2.2 Importance of cowpea

Cowpea is a multipurpose crop that is used as food, fodder and as a source of income (Karanja *et al.*, 2008). All the plant parts of can be used for food as they are nutritious containing proteins and vitamins (Islam *et al.*, 2006). This crop is nutritionally beneficial to human and animals and hence has been referred to as the poor man's source of protein in many rural and urban homes (Agbogidi, 2010b). It provides a cheap source of protein to the subsistence farmers with mean crude proteins for leaves, grains and crop residues at 32-34%, 23-35 and 11-12% respectively (Imungi and Porter, 1983).

Cowpea haulms are also dried on the rooftops and during the dry season used as fodder fetching as high as 50-80% of the seed price on dry weight hence providing a good source of household income (Singh *et al.*, 2003). It is reported that their calcium content is higher than that of fish, meat and egg while the iron equate that of milk; vitamins, riboflavin, thiamine and niacin and their levels compare to that of fish and lean meat (Achuba, 2006).

Cowpea has the ability to tolerate drought though it show variation in tolerance across various germplasm (Fatokun *et al.*, 2009) and some varieties perform poor when exposed to drought at reproductive stages (Agbicodo *et al.*, 2009). It is therefore suitable for growth in marginal areas that experience erratic rainfall and are drought prone (Hellensleben *et al.*, 2009). The crop is vital in farming system due to its ability to fix atmospheric nitrogen through symbiotic relationship with *Bradyrhizobia* species of bacteria capable of nitrogen fixing at an average rate of 240 kgN/ha per annum (Awurum, 2000) which allows it to grow and improve poor soils. It has a well-developed deep root system and grows well under drought conditions (Muruli *et al.*, 1980; Shakoor *et al.*, 1984; Woomer and Mulei, 2015).

Cowpea is important in food security both as a major vegetable as well as grain and hence in both forms it is sold to the urban markets and is wholly a woman's crop hence not receiving necessary attention from policy makers and researchers (Abukutsa-Onyango, 2011). In Eastern

Africa, dual-purpose cowpea varieties are most preferred since the small-scale farmers sequentially harvest leaves along the growing period and harvest seeds at the end of the season (Saidi *et al.*, 2007).

Cowpea leaves have been identified as one of the most important traditional vegetable in sub Saharan Africa along amaranth, nightshade, pumpkin leaves and African spider flower (Smith *et al*., 2005; Keding *et al*., 2007; Ekesa *et al*., 2009; Kiremire *et al*., 2010). It ranks third among the top five leafy vegetables consumed in sub-Saharan Africa in terms of the quantity consumed (Ekesa *et al*., 2009). Cowpea leaves are more popular in some area than seeds because they are produced earlier and in large quantities than seeds as well as the protein content being said to be more than 15times in leaves than in seeds (Mamiro *et al.*, 2011).

2.3 Production practices of cowpea

Cowpea is majorly grown in intercrop system and it is often intercropped with cereal such as maize, pearl millet and sorghum among others and less as a sole crop (Kossou *et al.,* 2001; Tungani *et al*., 2002; Langyintuo *et al*., 2003; Thuita, 2007; Salifou *et al*., 2017). This is because of its ability to withstand shading and other benefits such as maximizing productivity through diversification (Sulliva, 2003; Tungani *et al*., 2002; Woomer, 2007). This production system also ensures optimization of environmental factors such as moisture, soil nutrients and sunlight (Hussaini *et al*., 2001). Additionally it suppresses weeds and also curbs soil erosion (Suhi and Simbi, 1983). The crop fits in well to different cropping systems used by small scale farmers as well as capable of flourishing in marginal lands which can hardly support the growth of other agricultural crops hence enabling farmers to improve their income and food security (AATF/NGICA, 2006).

The element of intercrop has also been reported to result in higher productivity than in their respective pure stands, though they must essentially be different in their nutrient requirements or ability to withstand biotic and abiotic stress in order to be complementary (Hackett *et al.*, 2006). It has therefore been hypothesized that mixing of cultivars that are genetically different may result to a greater extent of stress adaptation across a range of environments (Helland and Holland, 2001). Intercrop also results to yield stabilization across different environments and reduction of intra-season diseases build up (Cowger and Weisz, 2008).

Seed selection of cowpea is normally from the harvested grain just after harvest or just before the next planting season. The selection is mainly based on grain size and colour with preference for big or small seeds varying from one locality to another, taste preference and yield potential (Orawu, 2007). The choice of varieties to be cropped is often also in reference to growth cycle and the resistance to insect pests and diseases and the market value of the crop based on the consumers' preference and the nature of the market (Houssou *et al*., 2010).

Post- harvest handling relate to sorting, drying and storage of cowpea grain. Sun drying requires periodic drying of the grains which helps reduce seed rotting due to high moisture content. Sorting while drying before storage reduces cowpea infestation during storage (Houssou *et al*., 2010). Too long storage should be avoided because prolonged time in storage leads to increased accumulation of aflatoxin (Kaaya and Kyamuhangire, 2006).

2.4 Constraints to cowpea production

Popularity of cowpea crop characterized by low yields points out a need to assess farmers' fields (Fatokun *et al*., 2002). The low yields have been attributed to high number of insect and disease pests which attack the crop at basically all its growth stages (Jackai and Singh, 1988; Alabi and Emechebe, 2004). Cowpea crop is majorly grown by resource poor farmers who continually use traditional methods of production hence unable to meet demands resulting to gradual abandonment of cowpea crop production (Paino D'urzo *et al*., 1990; Ahmed *et al*., 2010).

The crop faces the challenge of genetic erosion due to disappearance of the land races arising from multiple biotic factors such as diseases and pests. The genetic erosion is also as a result of farmers' failure to replenish their seed stock using certified seeds as they heavily really on sourcing seeds from the informal system which are of unknown quality (Paino D'urzo *et al.*, 1990; Mongo, 1996). This has also been as a result of farmers' abandoning cowpea production as it eventually becomes unprofitable due to huge losses resulting from diseases and insect pest attack (Paino D'urzo *et al*., 1990; Ahmed *et al*., 2010).

Cowpea is attacked by over 35 diseases resulting to effects such as root and stem rots, seed rot, seedling mortality, foliar diseases and deterioration of seed quality (IITA, 1982). These diseases are induced by a wide range of micro-organisms such as bacteria, viruses, fungus, parasitic nematodes and parasitic weeds (Alabi, 1994). Basically all parts of cowpea crop are attacked by insect pests at all growth stages which can cause up to 100% yield loss (Jackai and Singh, 1988). Emechebe and Lagoke, (2002) also reported that over 185 insect pests and 50 diseases attacked cowpea in Nigeria and the intensity of the damage varied from region to region. In Kenya, the poor yields among the smallholder farmers can also be attributed to poor yielding varieties, low soil fertility mainly N and P, low presence of effective indigenous rhizobia strains and the presence of ineffective indigenous strains (Mathu *et al*., 2012).

Bacterial blight of cowpea is one of the primary diseases of cowpea in the tropical and subtropical region favoured by the high temperatures and frequent rainfall (Silva *et al*., 1989; Ferreira *et al*., 2003). Yield losses resulting from this disease can be as high as 68% (Okechukwu *et al*., 2010). The causative agent *Xanthomonas axonopodis* pv *vignicola* is primarily seedborne (Sahin and Miller, 1997; Singh and Munoz, 1998).

2.5 Factors that affect quality of seed

Seed quality refers to the potential performance of a seed lot. Importance characteristics that greatly influence seed quality include; trueness to type, germination percentage, physical purity, moisture content, seed age, vigour, appearance and freedom from diseases (Ferguson *et al*., 1991; Louwaars, 2007; ISTA, 2015). Seed of high quality enables farmers to obtain crop stands with economical planting rate, high emergence, vigorous seedling establishment, uniform crop stand, uniformity in ripening and faster growth and high resistance to biotic and abiotic factors (Jarvis, 2001).

Physical purity analysis refers to the determination of the percentage composition of the sample obtained from a seed lot and the identification of the various components constituting of pure seeds, other seeds, other variety seeds, weed seeds and inert matter (Copeland *et al*., 1975; ISTA, 2015). High physical purity can be achieved via cleaning and sorting as well as proper storage to avoid damage by storage insect pests (Louwaars, 2007). Presence of off-types in a seed lot is considered a bleach of varietal purity and can cause disqualification of a seed lot during seed inspection and certification process (Gunjaca *et al*., 2008).

Physiological quality refers to all aspects of performance of the seed that include high germination and vigour. The germination percentage is an indicator of seedling emergence from the soil under normal conditions while seed vigour is the ability of seedling emergence under potentially unfavourable growing conditions and eventually fully develops under favourable environmental conditions. It is greatly influenced by the environmental condition under which the mother crop is grown (Ghassemi-Golezani and Mazloomi-Oskooyi, 2008). Decrease or loss of vigour happens long before germinability is lost (FAO, 2006).

Accelerated aging is a measure of vigour and is dependent on temperature and moisture content (ISTA, 2015). Loss of viability is faster in the presence of high moisture content which is essential to determining the longevity of seed (McDonald, 1999). Seed aging is determined by various cellular activities such as alteration of cell membrane, reduced energy metabolism, protein synthesis, RNA impairment and DNA degradation (Kibinza *et al*., 2006). The ability of seed to resist degradation and protection mechanisms which are species specific determines rate at which seed ages (Sismas and Delibas, 2004; Mohammed *et al*., 2011).

Seed health refers to the presence or absence of disease causing organisms such as fungi, bacteria, virus, nematodes and insect pests in a seed lot (ISTA, 2015). Seed health laboratory tests help assess the sanitary status of seed quality. Good seed health status can be achieved through proper seed production practices, which include control of pests and diseases during seed production process as well as elimination of diseases crops during growth and fumigation during storage (FAO, 2006). Seedborne pathogen infected seeds result to damages such as seed abortion, reduced seed size, seed rot, shrunken seeds, seed necrosis and seed discolouration (Icishahayo *et al*., 2007).

2.6 Seedborne diseases of cowpea their effect on seed quality

Cowpea is often attacked by a wide range of pathogens that include fungus, bacteria and virus which are seed borne and have adverse effect on growth and development of the crop (Zaidi, 2012). Major fungal seed borne diseases associated with cowpea include anthracnose (*Colletotrichum destructivum),* root rots *(Macrophomina phaseolina, Fusarium oxysporum* and *Curvularia lunata),* mycotoxin *(Aspergillus flavus)* (Sheety, 1992, Biemond *et al*., 2013). The primary seedborne bacterial disease is cowpea bacterial blight caused by *Xanthomonas axanopodis* p.v *vignicola (*Vauterin et al., 1994) previously known as *Xanthomonas* v*ignicola* (Bulkholder, 1944).

Transmission into seeds is reported to occur in three ways. Contamination of seed can be via the xylem of the mother plant as it happens in virus transmission, some fungi and other bacteria and reach the seed via the hilum. Pistil can also be an avenue of seed infection as a pathogen moves from the stigma through the style down to the embryo. Seeds can also be contaminated as they get into contact with infected fruit either at harvest or during threshing (Maude, 1996).

The process of seed infection, which is the establishment of pathogen in any part of a seed, is determined by the prevailing conditions in the environment in which a crop is grown (Darrasse *et al*., 2010). Seed microbes can be classified into; seed as primary source of inoculum, seed as a minor source of inoculum, bearing of seed borne micro-organisms that are non-pathogenic and infection of seeds in the field or in storage resulting to reduced yield and loss of seed quality (Darsonval *et al.*, 2009; Darrasse *et al*., 2010). The ability of a pathogen to cause infection is an implication of its fitness parameter in its transmission and disease initiation (Fenton *et al.*, 2002). Pathogen transmission through seed occurs when the pathogen moves from the seed to the seedling resulting into infection which is symptomatic or asymptomatic (Edreva, 2005).

Bacterial seedborne pathogen infection involves two stages namely endophytic stage and symptom inducing stage (Chalupowisz *et al.*, 2010). The endophytic stage involves the bacterial forming a point of attachment with the host plant surface via formation of biofilms or smaller aggregates. The interaction of the bacteria and the host cells is enhanced by production of adhesins by the bacteria which are polysaccharides and surface proteins (Danhorn and Fuqua, 2007). Adhesion of the bacteria to the host cells is an important step in bacteria pathogenesis (Coutte *et al.*, 2003).

After adherence during the endophytic stage the bacteria needs to develop mechanism to enable it to remain on or in contact with the host plant and multiply. This is because the host plant cells are already actively developing mechanisms to prevent the bacteria from entering and multiplying on it (Agrios, 2005). For a successful infection to occur there is development of a compatible host-pathogen interaction and the bacteria must overcome the immunity of the host (Jones and Dangl, 2006). Successful infection is characterised by development of symptoms such as discoloration and malformation or necrosis on plant parts while some infection remain latent and may show symptoms under favourable conditions or at maturity stage (Agrios, 2005).

Fungal seed borne pathogens are reported to use their hyphae to continually ramify through the protoplast cells as the cell membranes are disrupted. Toxins excreted by *Aspergillus flavus* causes rapid softening and necrosis of host cell (Mehrotra and Aggarwal, 2005). The factors influencing the development of seedborne fungus include moisture content of the grain, prevailing temperature and the level of infection with the pathogen (Trenholen, 1994).

Transmission of viral diseases via seed is known to occur in about one seventh of all known cowpea viral diseases and other hosts (Hull, 2002). Three important methods of transmission have been reported and they include direct or indirect injury of crop stand resulting from a seed lot with low incidence of viral infection. This provides a locus of inoculum for spread of the disease further by insect vectors. The second method involves the survival of viral inoculum in the soil or on crop debris from one season to the next. The third method involves dissemination of viroids and virus through germplasm exchange internationally with undetected infection (Albrechtsen, 2006).

In Africa, seven viral diseases of cowpea are considered seed borne. They include cowpea aphid-borne mosaic potyvirus (CABMV), black eye cowpea mosaic potyvirus (BICMV), cucumber mosaic cucumovirus (CMV), cowpea mosaic virus (CPMV), cowpea severe mosaic comovirus (CPSMV), Southern bean mosaic sobemovirus (SBMV), cowpea mottle carmovirus (CPMoV) (Hampton *et al*., 1997; Amayo *et al*., 2012). The rate of infection through seed depends on the genotype of the cowpea involved and strain of the virus (Ladipo, 1977; Aboul-ata *et al*., 1982). Cowpea aphid-borne mosaic potyvirus (CABMV), a potyvirus and Southern bean mosaic sobemovirus (SABMV) a sobemovirus are seed transmitted at the rate of 0-40% and 3-4% respectively (Thottappilly and Rossel, 1988).

Economic importance of viral diseases is paramount as they result to huge losses either due to their ability to infect a host singly or in multiples (Byoung-cheorl *et al*., 2005; Amayo *et al*., 2012). Viruses infecting in mixtures may result to synergism or antagonism in the infected plant and in cases whereby there is synergy the rate of infection is enhanced resulting to development of complex diseases (Vance *et al*., 1995; Fondong *et al*., 2000; Cho; 2000).

Antagonism occurs in cases where the co-infecting viruses are related which results to interference (Sakai *et al*., 1983) or cross protection (Watts and Dawson, 1980; Khan *et al*., 1994). Widespread effect of viral diseases is attributed to the favourable climatic conditions which prolongs vector migration hence enhancing vector population and consequently increasing their potential to transmit viruses (Vacke, 1983).

Seedborne pathogens have been reported to cause seedling mortality, reduced yields, low seed viability and germination (Emechebe, 1981; Richardson, 1990; Abdelmonen and Rasmy, 2000). The effect of these pathogens results to symptoms such as seed rot, necrosis, reduced seed size, shrunken seeds and other physiological alterations in the resultant seeds (Sheety, 1992). Among all seed borne pathogens, fungal pathogens cause the maximum seed damage characterized by reduced seed germination and vigour. Reduced germinability of the infected seeds may be attributed to the damage of the embryo by the deep seated infection (Zaidi, 2012). *Aspergillus* and *Fusarium* species are associated by the damage of endosperm, plumule, radical and hypocotyl of the germinating seedlings (Ngoko *et al*., 2001).

Seed borne viral cowpea diseases have been reported to have devastating effects causing symptoms such as stunting and plant deformation hence limiting the crops from attaining their potential (Booker *et al*., 2005). Kareem and Taiwo, (2007) reported that early infection singly or in mixes resulted to shortening of internodes and apical necrosis resulting to cessation of growth, stunting and subsequently death. The most appropriate means for management of these viral diseases has been reported to be the use of resistant varieties which are most economical, practical and effective (Taiwo, 2003).

2.7 Insect pests of cowpea and their effect on seed quality

Insects have been reported to be a major constraint in cowpea production (Jackai and Douast, 1986, Karungi *et al.*, 2000). Although cowpea crop is literally attacked by insect pests at every stage especially aphid (*Aphis cracivora)*, the most devastating ones attack at flowering and post-flowering which include flower bud thrips (*Megalurothrips sjostedti*), cowpea pod borer(*Maruca vitrata*) and pod sucking bug (*Clavigralla tomentosicollis*) (Jackai and Douast, 1986).

Aphids attack literally during all crop stages and all plant part including stems, leaves and young pods. Flower thrips attack during the flowering and suck sap leading to flower abscission while the cowpea pod borer feeds on the tender stems, flower buds, leaves and young pods (Karungi *et al.,* 2000; Alabi *et al.,* 2003; Egho, 2010). Inadequate management of these pests can result to very high yield losses (Singh and Jackai, 1985). Despite the much loss caused by field insects the most damage on cowpea seed of up to 80% result from attack by bruchids (*Callosobruchus maculatus)* on untreated cowpea seed during storage (Shade *et al.,*1990). Cowpea bruchids is the principal post-harvest pest in the tropics (Caswel, 1981).

Cowpea pests attack result to physical and physiological damage on the plant due to damage done on the leaves and in addition is the secondary infection which is quite first and lead to huge losses (Sariah, 2010). Grain losses that are attributed to cowpea field insects are 20-100% (Allen, 1980). Additionally, attacks by bruchids results to qualitative and quantitative losses evidenced by seed perforations hence reduction in weight, loss of market value and germinability of seeds (Oluwafemi, 2012). The losses by perforation on the seeds may be as high as 4-90% reducing the degree of usefulness of the cowpea either as seed for planting or even as grain for human consumption (Ali *et al.*, 2004; Umeozor, 2005). The loss of germinability of the seed is because the bruchids larva feeds on the seeds content in which within two generations can cause devastating damage (Ali *et al*., 2004; Swella and Mushobozy, 2007).

Management of cowpea insect especially bruchids which causes paramount damage by means of chemicals is expensive. This has resulted to food poisoning in cases where the storage period after treatment is not observed as well as environmental toxicity (Olakojo *et al*., 2007).

Therefore there have been efforts to manage this pest by use of resistant varieties which reduce the level of damage (Maina *et al*., 2006). However there have been reported cases of genetic resistant breakage of some improved varieties (Amusa *et al*., 2013) since most cowpea cultivars use monogenic resistance which is rapidly overcame by changes in pest populations (Leach *et al*., 2001).

Most cowpea farmers are resource poor and hence majority of them results to use of readily available local products such as ash, sand, dry pepper and botanical extracts (Beizhou *et al*., 2012). Reduction of F1 progeny has been reported in cases where natural plant products such as chillies and garlic have been used to treat seeds before storage (Tiroesele *et al*., 2015). Huang *et al*., 2000 reported that garlic contains methlallyl disulfide and diallyl trisulfide compounds which reduced egg hatching and subsequent emergence of progeny.

2.8 Bacterial blight of cowpea

2.8.1 Occurrence and geographical distribution

Bacterial blight of cowpea is one of the most widespread bacterial diseases of cowpea and has been reported widely in areas where cowpea is grown (Emechebe and Florin, 1997). It was first reported in Perkins, Oklahoma and Texas in 1931 and 1942 respectively. Its pathogen was first isolated from seeds and named *Xanthomonas campestris vignicola* by Bulkholder in 1944 (Preston, 1948).

This pathogen has subsequently been reported in many countries in Africa and India (Patel, 1981; Allen, 1980). Allen, 1980 observed that the disease was first reported to be in Tanzania in 1964 although Kaiser and Ramos, 1979 consider their work on bacterial blight to have been the first in East Africa. It was first recorded in Nigeria (Williams, 1975). The worldwide distribution of the disease is partly attributed to ability of the pathogen to infect seeds both of susceptible and resistant varieties (Saetller, 1989; Alabi and Emechebe, 2004).

2.8.2 Economic importance of bacterial blight of cowpea

Bacterial blight of cowpea remains to be the most damaging disease evident in all regions in the world where cowpea crop is grown (Saetller, 1989; Gobal, 1999). Primary infection via seed can lead to reduction of emergence by up to 67%. The remaining infected crops can cause secondary infection that can cause plant mortality of up to 81% and hence cause total yield losses of up to 92% all depending on the susceptibility of the cultivar and the growth stage at which the infection by the pathogen occurs (Kishun, 1989). Okechukwu *et al*., 2010 also reported that transmission of bacterial blight pathogen through seeds resulted to post emergence seedling mortality of 6-24% and blight incidence of 24-69%.

In locations whereby cowpea crop is commercially grown it has been reported to cause losses of pods attributed to pod lesions that subsequently can extend resulting to seed rotting and shrivelling. This results to pods, seeds and fodder losses at 71%, 68% and 53% respectively (Okechukwu *et al*., 2000). The percentage of seed transmitted level of bacteria blight incidence varies amongst varieties probably due to differential levels of infected seeds in harvested seed lots (Shoaga, 1998; Okechukwu *et al*., 2010).

2.8.3 Causal agent of bacterial blight

Cowpea bacterial blight is caused by the pathogen *Xanthomonas axanopodis* pv *vignicola* (Vautern *et al*., 1995) which was previously known as *Xanthomonas vignicola (*Burkholder, 1944). Considerable variations of these *Xanthomonas campestris* pv *vignicola* virulence has been reported (Khatri-Chetri *et al*., 1998a; Wydra *et al*., 2004) as well as variation in genetic composition (Verdier *et al*., 1998). Two main systems have been used to classify pathovars of Xanthomonas species. Biolog system has been used to classify this pathovars (Vauterin *et al*., 1995) while nutritional screening to identify DNA homology has also been used (Hildebrand *et al*., 1993).

2.8.4 Symptoms of bacterial blight of cowpea

Initial symptoms of bacterial blight are small water soaked spots and or light green areas on the leaves. The spots enlarge, centres become chlorotic then necrotic resulting to irregular shaped spots surrounded with lemon yellow ring that are diagnostic for this diseases and are either at the edge or at the interveinal space (Amodu, 2013). The spot may coalesce later leading to death of an entire leaf and subsequently defoliation of the plant (Hogquist *et al*., 1994; Amodu, 2013).

In cases of primary infection, the symptoms are on the cotyledons of the seedling emerging from infected seeds. The cotyledons appear reddish and wrinkled. Early necrotic lesions are formed on the leaves but later the stem is also attacked. The pathogen reaches the vascular bundle from whence it is transmitted systemically. The growing tips of the infected plant get necrotic and eventually die off. Cankers often develop on the stem near the point of union and the primary leaves and the stem becomes weak and hence cannot withstand strong winds as it easily breaks (Nandini *et al*., 2014).

Secondary infection appears on the leaves and it is characterized with light yellow circular spots that are 4-10mm in diameter and are all over the leaf lamina. The centre of the spot is necrotic and brown while the veins are red in colour. The spots on the pods are deep green or form water soaked streaks. Subsequently the pods become yellow, shrivelled and dies (Kishun, 1989; Nandini *et al*., 2014). The leafspots on cowpea caused by *Xanthomonas axonopodis* pv *vignicola* characterised by angular necrotic pustuliform, surrounded by a thin water soaked hallow has also been reported as a symptom of bacteria blight (Moretti *et al*., 2007).

2.8.5 Factors affecting bacterial blight development

The disease is heavy, early and causes infection on high humidity of 0-80%, under temperatures fluctuating between 20-25˚C and alternating dry and hot weather can result over 40% yield loss is susceptible cultivar (Serracin *et al*., 1991). A pathovar of the causative pathogen has been reported to cause serious problems especially under warm condition where it undergoes long epiphytic phase either as biofilms or solitary fractions (Jacques *et al*., 2005). The bacterium can also survive endophytically or on leaves surfaces (Gent *et al*., 2005; Darsonval *et al*., 2008).

Bacterial blight disease development has been reported to be influenced by various factors including strain of the bacterium, inoculum concentration, method of infection, host resistance and environmental factors (Aggour *et al.*, 1986; Bua *et al*., 1998). Photoperiod and stage of crop maturity at the time of infection has also been reported to be factors affecting disease severity (Arnaud- Santana *et al*., 1993).

2.8.6 Spread and survival of bacterial blight of cowpea

It is a pathogen majorly seed borne though it is also transmitted by soil, crop debris, insect and alternative hosts (Schuster and Coyne, 1975; Sirikou and Wydra *et al*., 2004; Zandjanakou, 2007. This pathogen can persist in the soil debris, seeds and plant debris for up to 8 months of off-season cropping beyond which it could not be traced in the soil and hence the main means of survival through seasons is the infected seeds and cowpea plant debris (Okechukwu and Ekpo, 2008). Bacterial survival on host and non-host plant include mechanisms such as invading and confinement in regions inaccessible by plant metabolism, avoidance of invoking inflammatory response, and molecular mimicry (Kenneth, 2011).

According to Nandini *et al*., (2014), infected pods produce small, wrinkled and diseased seeds that serve as a source of primary inoculum and secondarily spread by insects, rains and farm implements. Further spread of the pathogen may employ mechanisms such as admixtures, external seed surface and internally borne in seeds resulting to loss of germination, seed discoloration and shrivelling and toxin production (Fraedrick, 1996; Agrawal and Sinclair, 1996).

2.9 Management of seedborne diseases of cowpea

Management of some fungal seed borne diseases of cowpea such as anthracnose could employ strategies such as cultural measures, sanitation procedures, seed treatment and use of resistant varieties (Melotto *et al*., 2000). Cultural methods involves some practices such as cowpea crop rotation with non-host crops, burning or completely burying cowpea crop residues, intercropping and elimination of alternate weed hosts of the pathogen (Awurum *et al*., 2005; Than *et al*., 2008). It has also been articulated that proper management of the disease may involve measures such as good quarantine and regulatory procedures (Canon *et al*., 2012; Enyiukwu *et al*., 2014a; 2014b). Hot water therapy of seed at 50-55˚C for 20 minutes or hot air treatment at 40-45˚C can significantly reduce bacterial blight of cowpea incidence and severity without damaging the embryo (Miller and Lewis-Ivey, 2005).

Use of biological controls such as *Pseudomonas forescens* and *Bacillus subtilis* have been reported to manage major fungal seed borne pathogens such as Colletotrichum through antagonistic mechanism (Akinbode and Ikotun, 2008). Dressing of seeds with culture isolate *Trichoderma haziarum, T. viride* and *Gliocladium virens* for 15 minutes before sowing reduced infection by *Colletotrichum lindemuthianum* and led to increased bean seed germination (Mohammed, 2013). Use of plant derived pesticides such as *Uvaria chamae* has effectively been used to as seed dressing phytochemical against anthracnose disease (Awurum *et al*., 2005). Extracts from some tropical spices *Piper guineense, Xylopia aethipica, Monodora myristica* were strongly effective in as seed dressing phytochemicals and storage protectants against anthracnose (Awurum and Ucheagwu, 2013; Awurum and Enyiukwu, 2013).

2.10 Methods of testing quality of cowpea seed

Testing methods for seed quality include physical purity analysis, seed health tests, germination and vigour test as describes by ISTA 2015 rules. Physical purity analysis involves picking a randomly picked sample of known weight from the seed lot and placing them on the separating board. The seed sample is separated into four constituents that are pure seed, weed seeds, other seeds and inert matter (FAO, 2006; ISTA, 2015).

Germination test is carried out in the laboratory on pure seeds to test out the germination potential of a seed lot and subsequently the planting value. It involves growing the seeds in a media whereby for cowpea between paper method and grow on test on sand is used. The seeds are incubated at 20-30°C and the first and second count is done at 5 and 8 days respectively. The seedling are then assessed and categorized as normal seedlings and abnormal seedlings, hard, fresh and dead seeds. The number is expressed in percentage and rounded off to the nearest whole number (ISTA, 2015).

Seed health tests are carried out to detect the presence or absence of any pathogenic microorganism such as fungi, bacteria and virus as well as nematodes and insect infestation. Testing for bacterial seedborne pathogens such as *Xanthomonas* sp, 50gms of seed are counted, their number determined and the weight of a thousand seeds calculated. The seeds are then suspended in pre-chilled sterile saline with 0.02% Tween 20 in a conical flask. The seeds are then put in on an orbital shaker of 100-125rph for 2.5 hours. The extract is then serially diluted tenfold and plated in appropriate media (ISTA, 2015). Four seed health testing methods: seed soaking, seed maceration, blotter test and grow on test can be used for detection *Xanthomonas axonopodis* p.v *vignicola*. Out of the four, seed-soaking test is the most superior (Anitha *et al*., 1992).

Use of seed soaking test to recover the bacterium from infected seed can be enhanced by the use of selective and semi selective diagnostic medium SIBU and Nutrient Starch cycloheximide antibiotic agar (NSCAA) (Khan *et al*., 1994). Claudius-Cole *et al*., 2014 reported that use of pathogenicity on various parts of cowpea, pod inoculation was the most effective followed by young plants and excised embryo and that the use of stems and petiole were the least effective. Further tests for this pathogen on various parts of a cowpea seed have shown that hilum is the most colonized part and that bacteria found in and around the hilum will be found in the testa and cotyledons (Amodu *et al*., 2013; Claudius-Cole *et al*., 2014).

Detection of seedborne fungal pathogens may employ a combination of techniques such as visual examination internally and externally for presence of macro and microscopic fungal structures, incubating seeds on agar or use of moist blot papers. This is followed by identification of the pathogen microscopically (Warham *et al*., 1990; ISTA, 2015). Direct examination is capable of detecting smut balls, sclerotia, fungal spores and other fruiting bodies such as pycnidia, acervulus, and perithicia among others (Kameswara and Bramel, 2000). It may also indicate presence of pathogens in cases where the seed are discoloured or shrivelled hence calling for further diagnostics (Agarwal and Sinclair, 1997). Incubation tests on agar or blot paper provide a favourable environment for development of pathogen as well as features used for identification like septation, conidiophores arrangement among others (Warham *et al*., 1990).

Viral seedborne diseases are detected using serological methods that are antibody-based methods that are highly sensitive and efficient especially for large scale testing (Albrechtsen, 2006). Polymerase chain reaction (PCR) and protein sandwich enzyme linked immunosorbent Assay (PAS ELISA) (Hughes and Thomas, 1988) are recent nucleic- acid based methods with higher specificity, great sensitivity and are self-automated. However, these methods are not simple and are expensive for developing countries (Ojuederie *et al*., 2009). Use of meristemtip culture method has come handy in ensuring transfer of germplasm across countries while eliminating seedborne virus borne in grain legumes (Kartha *et al*., 1981).

2.11 Cowpea seed systems in Kenya

Kenyan farmers mainly depend on three seed systems namely informal seed systems supply, integrated seed system and the formal seed supply system (Munyi and De Jonge, 2015). Informal seed system has plurality in that it can be divided into three categories namely; farmer based seed systems, community based seeds systems and relief seed systems. Farmer based seed system implies individual farmer saving their seeds, exchanging seed with neighbours or purchasing the same seeds at the local market (Almekinders and Louwaars, 1999). Over 75% of cowpea seed used in Kenya is obtained from farm based seed system (Ayieko and Tschirley, 2006).

The integrated seed system refers to improvement of the local seed supply by borrowing technologies and improvement from the formal system into the informal system provided by the local research centres such as KARLO and other agricultural oriented research institutes. The limitation in this system is the lack of linking key players in the seed value chains. Formal seed systems involve production and supply through defined mechanisms and methodologies (Wekundah, 2012). The informal seed system account for over 80% being used in the country and much higher in the ASALS. Increase in agricultural productivity for small and medium scale farmers requires a well performing seed system (FAO, 2014). In general, majority of the farmers have stuck to the use of local accessions and landraces that they prefer due to their high palatability compared to the more improved varieties such as K80 and KVU (Hutchinson *et al*., 2016; KARI, 2010).

In Eastern Kenya, there has been a drastic change in seed supply since 2010 with the inception of Dryland Seed Company (DLSC) that collaborated with USAID to commercialize the production and sales of certified seeds that are adaptable to dry conditions. This was achieved through introduction of high yielding seed varieties through field days, demonstrations and linkages to agro-dealers. Cowpea makes up 37% of all produced in Kenya. The seeds are produced in public-private partnership licensing agreement with KALRO and the seeds are certified by KEPHIS and thereafter distributing from DLSC main distributor in Machakos town and down to the retailers. Dry Land Seed Company and USAID partnership aimed at introducing farmers to use of certified seeds since seeds are vital in increasing the farmers' production and income. Cowpea varieties that have since been released include M66, K80, KVU 419 and KVU 27-1 (Karanja *et al*., 2008). Cowpea seeds are mainly produced by public research institutions since the demand is too little to be supplied by private companies who are profit oriented and thrive on high demand for a huge profit margin (Kimani *et al*., 2014).

CHAPTER THREE

PRODUCTION PRACTICES AND QUALITY OF COWPEA SEED USED BY FARMERS IN TAITA TAVETA AND MAKUENI COUNTIES

3.1 Abstract

Over 80% of farmers in the developing countries use seeds from the informal seed supply that are of unknown quality status with low physical purity, reduced vigour and contamination with seed borne pathogens. A survey involving 114 farmers was conducted in Makueni and Taita counties using a semi-structured questionnaire to determine cowpea production practices. Forty-seven cowpea seed samples were collected from farmers and 34 were collected from markets across the study areas and were analysed for physical and physiological quality. The data from the questionnaire was analysed using SPSS package. The seed samples were analysed for physical purity and physiological quality as per ISTA rules. Over 76% of farmers used farm saved seeds while the major cowpea cropping system was intercropping with cereals used by over 56% of farmers. The main containers were polythene bags (56%) and farmers did not treat their seeds. Pure seed composition of seed samples from both sources were below the recommended standard of 98%. The seed samples did not meet the recommended germination capacity of 80% and were of low vigour. Farmers should be enlightened on recommended production practices, methods of harvesting and postharvest handling practices to reduce seed quality loss during storage and maximize production.

Key word: Production practices, farm saved, seed quality, *Vigna unguiculata*

3.2 Introduction

Cowpea is an annual or biannual grain legume that is very important and ranked among the top most important legumes in the world, second in Africa and third most important in Kenya (Kimiti *et al*., 2009 Awurum and Enyiukwu, 2013). Its suitability for Sub Saharan Africa due to its ability to grow in adverse climatic conditions which are ever expanding due to climate change whereby other legume crops cannot flourish well. In Kenya, 85% of its production area is in the arid and semi-arid areas of Eastern province and the rest of 15% is in Nyanza, Central and Western provinces (Muthamia and Kanampiu, 1996; Muli and Saha, 2000).

Cowpea is intercropped with cereals like maize and sorghum hence contribute to soil fertility and sustainability in complex cropping systems in the ASALS (Woomer and Mulei, 2015). It also has the ability to grow under drought and also low soil fertility conditions and still produce leaves even though not to its optimal ability during such weather (Ayieko and Tschirley, 2006). Two of the varieties released in Kenya at Katumani in earlier years are Machakos 66 and K80 both of which are dual purpose, drought tolerant, giving yields of 1.3t/ha and 1.5t/ha respectively and adapted to altitude of above 1,300m and below 1300m respectively (Kimani *et al*., 2014). Low yields are significant attribute of production estimates, particularly in Africa where 240-300kg /ha are often realized (Rachie, 1981; Kimiti *et al*, 2009).

Recent studies by the Ministry of Agriculture, Livestock and Fisheries in Kenya have reported a decrease in number of bags per ha despite the increase in the land under cowpea which could be due to low seed quality. Seed quality is a description of a seed in terms of physical quality, genetic quality and seed health (Louwaars, 2007). Cowpea farmers are only willing to buy small amount of seeds once and recycle them in the subsequent seasons and years. Most of the seed producing companies are private and hence are profit oriented and are therefore unwilling to produce these seeds and in addition to distributing small amounts of seed over long distances in the rural areas and hence the seeds do not reach the farmers and they result to seed recycling (Kimani *et al*., 2014).

Continuous seed recycling over the years leads to loss of seed quality over time and eventually results to poor grain yields (Amaza *et al*., 2010). High seed quality is characterized by the nature of the genotype of the parent material as it determines the response of the plant to abiotic and biotic factors in the field and ultimately determines the yield potential. Quality seed is essential in ensuring the establishment of optimum crop stand that directly affects yields (McGuire, 2005). The seed quality is affected by many aspects in its production such as seed source, production practices and management, cropping system, harvesting and post-harvest handling especially in grains that are also used as informal seeds. Therefore, there is need to determine the cowpea farmers' production practices and the quality status of the seeds used by farmers in Makueni and Taita Counties in Kenya.

3.3 Materials and methods

3.3.1 Description of the study area

The study was conducted in Wote and Makindu sub-counties of Makueni County and in Mwatate Sub-county of Taita Taveta County. Wote sub-county lies in Lower midland subzone IV (LM4) and receive a bimodal type of rainfall with the long rains occurring between March and April and the short rains occurring between November and December. It receives rainfall of 800-1200 mm per year with cool temperatures ranging from 20.2°C to 24.6°C. Makindu and Mwatate sub- counties lie at Lower midland subzone V (LM 5). The areas experiences bimodal rainfall patterns with the long rains between March and May and the short rains between November and December. An average annual rainfall of 157-1200 mm is received in these areas while mean temperature varies at 18-25°C (Jaetzold *et al.*, 2006).

3.3.2 Determination of cowpea seed production practices in Makueni and Taita Taveta Counties

A survey involving 114 farmers was conducted using a semi-structured questionnaire (Appendix 1) using a purposive sampling technique during 2016 short rain. The questionnaire was only administered to farmers who were growing cowpea. The information captured included types of seeds used, sources of seeds used, cowpea varieties grown, number of seasons, and area under cowpea, cropping systems, production trends, harvesting and post harvesting handling of cowpea seeds. Thirty-three farmers were interviewed in Wote, 26 in Makindu and 55 in Mwatate. Farmers were requested for at least 500 g of cowpea seeds and they were carried to the laboratory for physiological quality.

Cowpea seed samples were also collected through random sampling in three major markets in the areas of study namely Mwachabo, Makindu and Wote markets located in Mwatate, Makindu and Wote areas respectively. Seeds collected from markets were also carried to the laboratory for physiological quality analysis. The sample size was determined using the formula below:

$$n = \frac{N}{1 + N(e)2}$$

Whereby n is the size of the sample, N is the population size and assumptions of the formula is 95% confidence interval, P=0.5 and error limit (e) =0.1 (Barrett *et al.*, 2011)

3.3.3 Determination of physical purity

Cowpea seed samples collected from the farmers and from markets were analysed for physical purity according to International Seed Testing Association (ISTA, 2015). Purity tests were done on 4 replicate of a 100 g each. Each of the samples was separated into six constituents of pure seed, other varieties seeds, other crop weed seeds, discoloured/ shrivelled seeds and inert materials on a separating board with the aid of separating knife and magnifying lens. This procedure was replicated four times to attain the recommended sample of 400 g. The composition of each was measured on weight basis and the percentage component calculated using the following formulae:

$$\text{Component (\%)} = \frac{\text{Weigt of each component (g)}}{\text{Weight of total test sample (100g)}} x100$$

3.3.4 Determination of germination and vigour

Between paper towel method was used to determine the two physiological quality aspects of the cowpea seed samples. Four hundred seeds of each sample were divided into four replicates of a 100 seeds each. The seeds were surface sterilized in 2% sodium hypochlorite for four minutes and then subjected to three subsequent rinses in distilled water to wash away the sodium hypochlorite. Sterilized sandwich boxes were lined with three layers of blotting papers, moistened with sterile distilled water and a 100 seeds were placed on the moistened blotting paper where by each replicate was put in two sandwich boxes each with 50 seeds. They were covered with two layers of the blotting paper, moistened and then sealed. The entire working sample was taken through the same process ensuring each test had 400seeds.

The samples were incubated at room temperature and assessed for germination on the 5th, 7th and 9th on which the seedlings were assessed for germination on the 5th and 7th day. On the 9th day, the seeds were assessed for normal seedlings, abnormal seedlings, infected seedlings as well as the dead, hard and mouldy seeds. After the 9th day, the seedlings were assessed for seedling length and dry mass for use to determine the seedling vigour index (ISTA, 2015).

Germination indices that included germination percentage, germination index and germination rate index were calculated from the germination data as per Olisa *et al.*, 2010 while the seed vigour index was calculated according to Abdul-Baki and Anderson, 1973:

$$\text{Germination (\%)} = \frac{\text{No. of emerged seedlings at the final count}}{\text{Total number of seeds planted}} \; x\ 100$$

$$\text{Germination Rate(GR)} = \frac{\sum(Nx)(DAS)}{\text{Total number of seedlings that emerged at the last count}}$$

Whereby Nx is the number of seedlings that emerged on day X after planting and DAS is the day after planting.

$$\text{Germination Rate Index} = \frac{GP}{\text{GI}}$$

$$\text{Vigor index I} = \text{Germination \%} \times \text{Seedling length}$$

The seedling length was computed by randomly selecting 10 normal seedlings from each replication and the root length was measured from the point of attachment to the seed to the root tip using a ruler while the shoot length was measured from the point of attachment to the seed to the shoot tip (Oshone *et al*., 2014). The average shoot and tip length were computed by dividing both lengths by 10; the total number of normal seedlings measured (ISTA, 2016).

$$\text{Vigor index II} = \text{Germination \%} \times \text{Seedling dry weight}$$

Normal seedlings from each of the replicates used in the germination test were put in small khaki bags and the weight determined. The seedlings were oven dried at 60°C until the weight became constant to obtain the total dry weights (Oshone *et al*., 2014).

3.4 Data analysis

The data obtained from the survey was subject to analysis using SPSS Statistical Software version 20.The parameters analysed included types and sources of seeds, varieties grown and number of seasons, area under cowpea, cropping system, production trends, harvest and post-harvest handling practices to determine the percentage frequency of the respondents and the respective production frequencies. The data obtained from purity analysis and physiological quality was analysed using GENSTAT© statistical package and means separated using Fisher’s protected LSD at $P \leq 5\%$.

3.5 Results

3.5.1 Production practices and postharvest handling of cowpea seed by farmers in Wote, Makindu and Mwatate

Up to 76% of farmers in Wote were using uncertified cowpea seed that was almost three times of the percentage using certified seeds. In Makindu area all the respondents were producing cowpea from uncertified seeds while in Mwatate a significant number of farmers were producing cowpea from certified seeds (75%) hence the respondents in this area used little of uncertified seeds than the other two regions (Table 3.1)

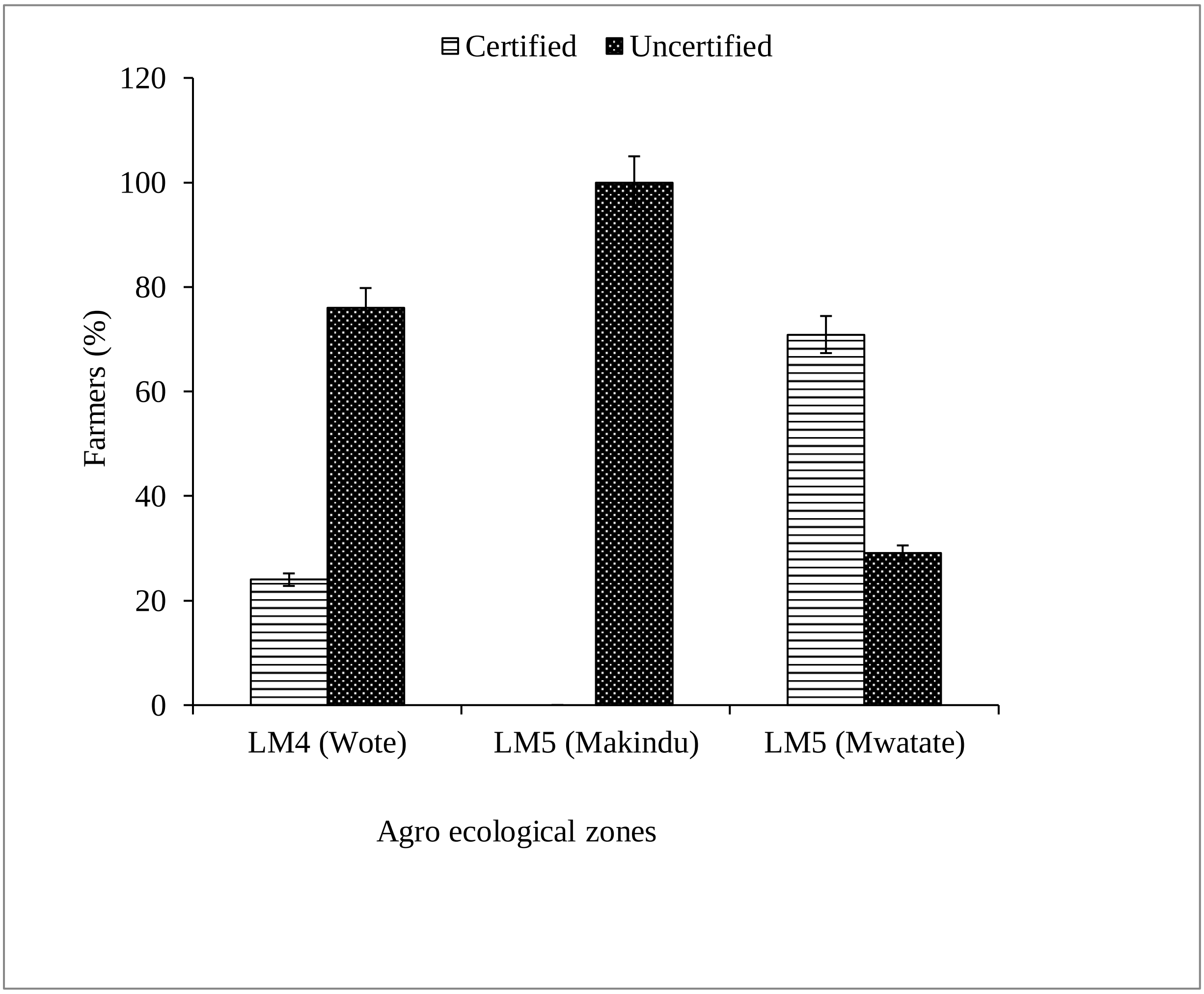

Figure 3.1: Percentage of farmers using certified and uncertified cowpea seed in various agro-ecological zones in Makueni and Taita Taveta during 2016 short rains

Farmers in the areas of study were using both certified and uncertified seeds. There was a significant difference in the number of farmers who were using uncertified seeds of farm saved origin in the three areas of study whereby it was highest in Mwatate which it was more than twice the use of these seeds in Wote. Use of uncertified cowpea seeds of market origin was significantly different between Wote that had the highest and the other two areas in which the use was not significantly different (Figure 3.2).

Percentage of farmers using seeds borrowed or bought from other farmers was significantly different between the two areas namely Makindu and Mwatate whereby the use in the latter was almost thrice the use in Mwatate whereas there no farmers used seeds from other farmers in Wote area. A few farmers in Makindu had ever used certified seeds from CBO/ NGO. There was a significant difference in the use of certified seeds from the Agrovet between the three areas whereby Mwatate had the highest percentage of farmers who sourced their seeds from Agrovet which was more than thrice the farmers from Wote and none of them sourced for seeds from Agrovet in Makindu area. Access of seeds from research institutions was significantly different between farmers from Wote and Mwatate whereby Wote had the highest percentage of such farmers (66.7%) followed by Mwatate (6.7%) which was almost more than ten times those in Mwatate (Figure 3.2).

Recycling of cowpea seed was practised by most of the farmers in the three areas of study. Across the three regions the highest mean percentage of farmers were recycling seeds for up to 2-3 seasons with Wote having the highest followed by Mwatate and in Makindu which was twice less those in Wote. The percentage of farmers using seed for a season was almost equal across the sites at 24% and it was the second highest after those who recycled for 2-3 seasons. Very few farmers recycled seeds for more than 10 seasons the highest being by farmers from Makindu at 6.3% (Table 3.1).

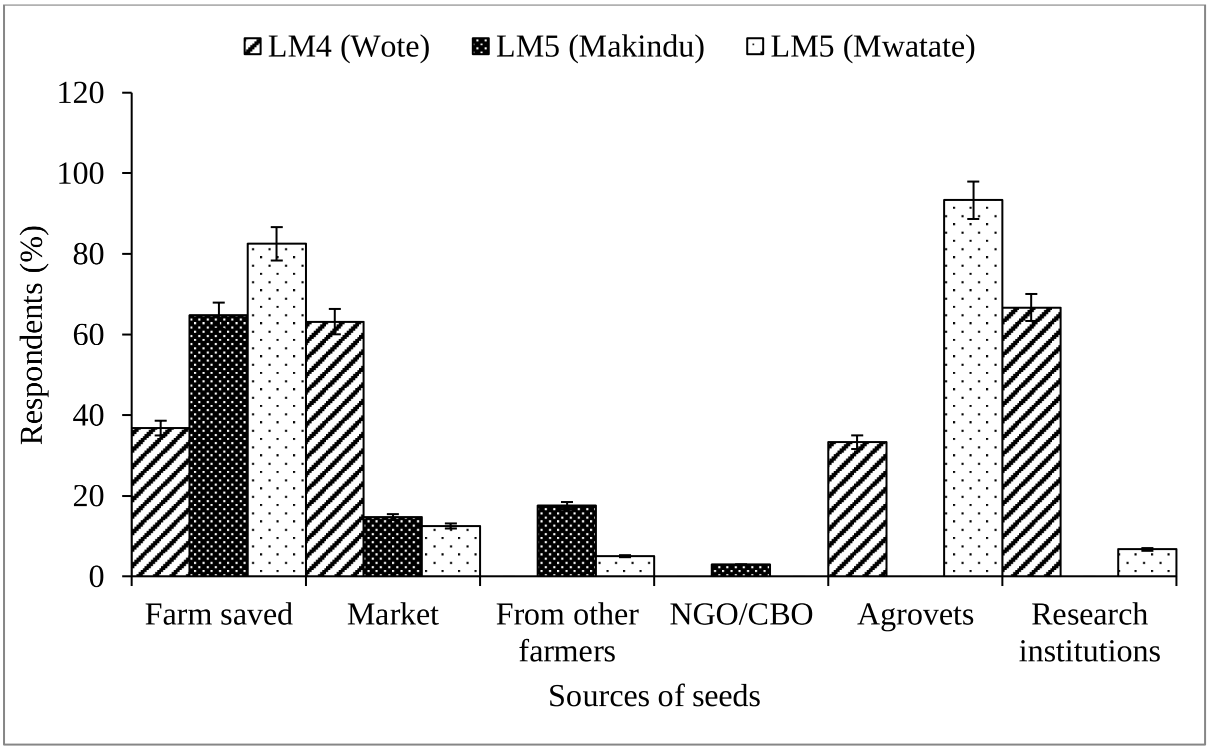

Figure 3.2: Percentage of farmers who obtain seeds from different sources in various agro-ecological zones in Makueni and Taita Taveta during 2016 long rains

Table 3. 1: Percentage of farmers using cowpea seeds for indicated seasons in various sub-counties in Makueni and Taita Taveta Wote, Makindu and Taita during 2016 long rains

Season	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)	Mean
One	22.2	25.0	25.0	24.0
2-3seasons	55.6	18.8	37.5	37.3
4-8 seasons	11.1	12.5	29.2	17.6
> 10 seasons	0.0	6.3	4.2	3.5

LM4- Lower Midland Zone IV, LM5- Lower Midland Zone V

Land area under cowpea in Wote and Mwatate was 0.25acres at 88% and 82% respectively. In Makindu, most (53%) of the respondents had 2-4 acres of land under cowpea. Only 9% of farmers grew cowpea on more than 4acres in Makindu (Figure 3.3). Mixed cropping was significantly different across all areas Wote (84%), Makindu (67%) and Mwatate (56%). Preference of mono-cropping was significantly different in the three sites and had an inverse relationship with the mixed cropping system such that the pure stands were highest in Mwatate followed by Makindu and Wote at 44%, 34% and 16% respectively (Figure 3.4).

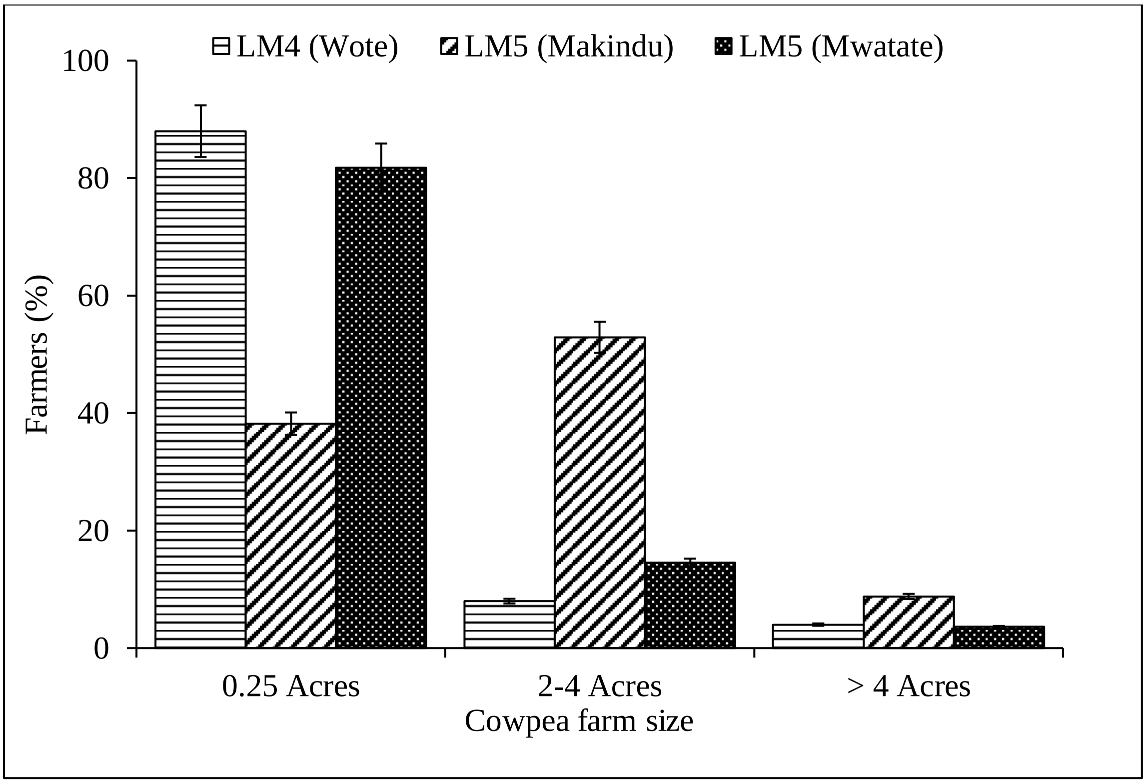

Figure 3.3: Percentage of farmers growing cowpea in various farm sizes in various agro-ecological zones in Makueni and Taita Taveta during 2016 short rain

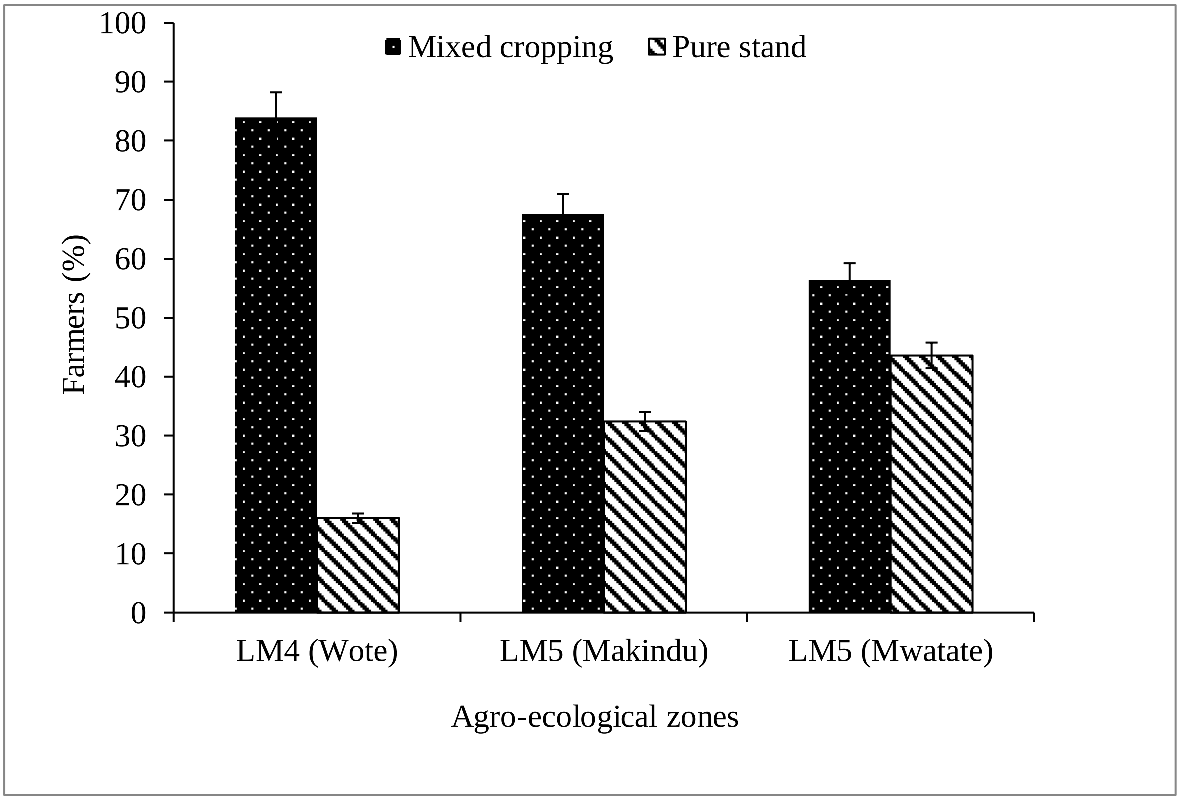

Figure 3. 4: Percentage of farmers growing cowpea on pure stand and mixed cropping in various agro-ecological zones in Makueni and Taita Taveta during 2016 short rain

During 2015 short rains, the highest percentage of farmers obtained 201-500 kg/ha with Wote having the highest followed by Makindu and Mwatate. Percentage of farmers in Wote and Makindu obtained these yields was up to five times compared to those in Mwatate. A considerable percentage of farmers who harvest nothing during this season across the three areas with the highest from Mwatate (26.9%) followed by Wote (20%) and Makindu (8.8%). It was also noted that none of the respondents harvested over 500 kg/ha (Table 3.2).

During the long rains 2016, the highest mean percentage of farmers (20.5%) had a yield range of 201-500 kg/ha followed those at <10 kg/ha (17.7%). During the long rains 2016, Wote and Makindu recorded 201-200 kg/ha as the highest yields at 20% and 32.4% respectively unlike in Mwatate where most of the farmers got <10 kg/ha at 40% of the farmers. Higher maximum yields of over 500 kg/ha were obtained in the long rains in Wote (12%) and Mwatate (1.8%) (Table 3.2).

The main threshing method was physical hitting after uprooting the crop by all farmers in Wote and Makindu unlike Mwatate (97.9%) with the rest using manual threshing. Sun drying was the main drying method used by 96%, 97.1% and 85.7% in Wote, Makindu and Mwatate respectively. However, few farmers in Mwatate (12.2%) dried their produce in the field before harvesting. Farmers used various methods of storage; house racks, granaries and kitchen (Table 3.3).

Most of the farmers used house racks and granary as main storage places. House racks were most popular in Taita (74.5%) followed by Wote (24%) and Makindu (14.7%). Granary use for storage was most popular in Makindu (85.3%) of the farmers employed it followed by Wote (76%) and was least used in Taita (23.5%). Storage of harvested cowpea in the kitchen was only employed in Taita only whereby 2% of the respondents stated that they used it as a means of storage (Table 3.3).

Table 3.2: Percentage of farmers and the corresponding production levels in 2015 short rain and 2016 short rain in various agro-ecological zones in Makueni and Taita Taveta

Production level (kg/ha)	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)	Mean
Short rains 2015				
0	20.0	8.8	26.9	18.6
< 10	12.0	8.8	38.5	19.8
10-50	0.0	17.6	9.6	9.1
51-100	12.0	17.6	3.8	11.1
101-200	8.0	5.9	5.8	6.6
201-500	44.0	41.2	9.6	31.6
>500	0.0	0.0	0.0	-
Long Rains 2016				
0	0.0	5.9	27.3	11.1
< 10	8.0	11.8	40.0	19.9
10-50	8.0	32.4	12.7	17.7
51-100	12.0	8.8	7.3	9.4
101-200	0.0	8.8	0.0	2.9
201-500	20.0	32.4	9.1	20.5
>500	12.0	0.0	1.8	4.6

LM4- Lower Midland Zone IV, LM5- Lower Midland Zone V

The assessment showed usage of five types of cowpea seed storage containers; nylon sacs, gunny bags, plastic containers, pots and reed baskets. Across the three areas of study the most popular storage container were the nylon sacks which most popular in Makindu (91.2%) followed by Wote (64%) and Mwatate (55.8%). The second popular storage container was the plastic containers at 20% and 28.8% at Wote and Mwatate but was not being used at all in Makindu. Use of gunny bags was relatively similar in the three areas as they were at 8.8%, 8% and 3.8% in Makindu, Wote and Mwatate respectively. Plastic bags, Pots and basket reeds were not used at all in Makindu as they heavily relied on plastic sacks and gunny bags (Table 3.3).

The study showed that the seed treatments used in the areas of study varied from place to place which included Actellic super, Scanner super, ash and others such as paraffin, oil and smoke. The most popularly used product for seed treatment was the Actellic super whose use was highest in Wote (95%) followed by Makindu and Wote at 57.6% and 55.9% respectively. The second most popularly used product was ash which was used in Makindu and Mwatate at 42.4% and29.4% respectively. Scanner super was not used in Wote and Makindu while ash was only used in Makindu (42.4%) and Mwatate (29.4%). Other products which included smoking, oil and paraffin were only used in Wote by only 5% of the respondents (Table 3.3).

Table 3. 3: Percentage of farmers using various postharvest handling practices of cowpea seeds in various agro-ecological zones in Makueni and Taita Taveta during 2016 long rain

Threshing method	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)
Physical hitting	100.0	100.0	97.9
Removal by hand	0.0	0.0	2.1
Drying methods			
Sun-drying after harvesting	96.0	97.1	85.7
Sun-drying before harvesting	4.0	2.9	12.2
Storage place			
House racks	24.0	14.7	74.5
Granary	76.0	85.3	23.5
Kitchen	0.0	0.0	2.0
Storage containers			
Nylon bags	64.0	91.2	55.8
Gunny bags	8.0	8.8	3.8
Plastic containers	20.0	0.0	28.8
Pots	4.0	0.0	7.7
Reed baskets	4.0	0.0	3.8
Treatment before storage			
Pirimiphos methyl	95.0	57.6	55.9
Malathion 2% + Permethrin 0.3w/w	0.0	0.0	9.1
Ash	0.0	42.4	29.4
Others(Paraffin Oil, Smoking)	5.0	0.0	0.0

LM4- Lower Midland Zone IV, LM5- Lower Midland Zone V

3.5.2 Effect of seed source on the physical purity

The mean purity percentage of the farm saved and market sourced seeds in the various agro ecological zones was at 73.7% and 84.7% respectively. Purity in the farm saved seed was significantly different between Wote, which was the least (61.6%), and the other two areas namely Mwatate and Makindu that were the highest and not significantly different at 82.1% and 79.3% respectively. Purity in market-sourced seed was significantly different between Mwatate which was the least at 80.2% and the other two sites The second highest composition of the seed both from the farm saved and the market sourced was the insect damaged seeds. The mean composition was 20.3% and 9.6% in farm saved and market sourced seed respectively (Table 3.4).

The percentage of other varieties and was the third highest component and it was similar to the percentage composition of other crop seeds whereby Mwatate had the highest which were significantly different to the other two areas. Percentage of insect damaged seeds was significantly different across the three areas of study with Wote having the highest (33.6%) followed by Makindu and Mwatate at 15.9% and 6.7% respectively. In farm saved seed it was significantly different across the three areas of study which were the highest and not significantly different. The percentage composition of shrivelled seeds and inert matter was not significantly different across the three areas of study (Table 3.4).

Percentage purity of market-sourced seeds was highest in Makindu and Wote at 91.2% and 90% that were significantly different with those from Mwatate that had a percentage purity of 80.2%. Percentage composition of other variety seeds and other crop seeds were not significantly different across the three areas of study. Composition of insect damaged seeds and inert matter was significantly different between Wote which had the highest at 13.2% and 2.3% respectively and the other two areas whereas the percentage composition of shrivelled seeds was highest in Wote (1.2%) which was significantly different from the other two regions (Table 3.4).

Table 3. 4: Percentage physical purity components of cowpea seeds obtained from various agro-ecological zones in Makueni and Taita Taveta during 2016 long

Agro-ecological zones	Pure seed	Other variety	Other crops	Insect damaged	Inert Matter	Shrivelled
Farm saved						
LM5 (Mwatate)	82.1a	7.9a	1.1a	6.7c	1.5a	1.5a
LM5 (Makindu)	79.3a	2.0b	0.4b	15.9b	2.1a	0.7a
LM4 (Wote)	61.6b	1.1b	0.3b	33.6a	2.0a	1.5a
Mean	73.7	2.8	0.5	20.3	2.0	1.1
LSD (p< 0.05)	17.3	4.4	1.0	16.4	1.2	2.1
CV %	29.8	198.3	264.8	102.8	80.5	241.3
Market sourced						
LM5 (Makindu)	91.2a	0.8a	0.3a	5.5b	1.3b	0.9b
LM4 (Wote)	90.0a	3.7a	0.4a	4.6b	1.1b	1.2a
LM5 (Mwatate)	80.2b	2.3a	0.7a	13.2a	2.3a	1.1b
Mean	84.7	2.3	0.5	9.6	1.8	1.2
LSD (p< 0.05)	14.2	4.5	0.9	14.9	1.0	0.9
CV %	19.2	219.6	195.2	177.4	61.4	86.3

Means with different letters are significantly different (p< 0.05) with the Fishers multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance**,** LM4- Lower Midland Zone IV, LM5- Lower Midland Zone V

3.5.3 Effect of seed sources on germination and vigor

The mean germination percentage of farm saved and market sourced seeds was at 68% and 76% respectively. In farm saved seed the highest germination percentage was recorded in Mwatate (86.6%) which was significantly different from the ones from Wote (61.1%) and Makindu (61.2%). Germination percentage of farm saved seeds was highest in Mwatate (38.1) which was also significantly different with the ones from Wote and Makindu (Table 3.5).

Number of normal seedlings was not significantly different in seeds from the three areas and ranged from 15-16 seedlings. Farm saved seeds from Mwatate had the highest number of abnormal seedlings (52) which was significantly different from the seeds from the other two areas. Hard seed composition was highest in the seeds from Mwatate (3) which was also significantly different with the seeds from the other two areas (Table 3.5).

Germination percentage of seeds sourced from the market varied across the regions. Seeds from Mwatate had the highest germination percentage (80.5%) which varied significantly with the seeds from Wote and Makindu at 73.7% and 67.1% respectively. The highest germination rate was on the seeds from Mwatate (35.6) which was significantly different from the seeds from Wote (29.4) and Makindu (26.6). Number of normal seedlings was highest in seeds from Mwatate (18) which was significantly different from the seeds from Wote and Makindu both at 10 seedlings. Number of abnormal seedlings was highest in Wote and Makindu at 51 and 54 seedlings respectively which were significantly different with the seeds from Mwatate (36) while hard seed composition was highest in seeds from Wote which was also significantly different with the seeds from the other two areas (Table 3.5).

Table 3. 5: Percentage viability of farm saved and market sourced seeds from different agro-ecological zones in Makueni and Taita Taveta

Agro-ecological Zones	Germination (%)	Germination Rate	Normal Seedlings	Abnormal Seedlings	Hard Seed
Farm saved					
LM5 (Mwatate)	86.6a	38.1a	16.2a	52.3a	3.1a
LM4 (Wote)	61.2b	25.7b	15.1a	33.7b	1.3b
LM 5 (Makindu)	61.1b	25.6b	15.2a	33.7b	1.3b
Mean	68.0	29.0	15.5	38.8	1.7
LSD (p< 0.05)	20.1	8.2	10.7	13.7	2.7
CV %	37.6	36.2	88.0	44.9	196.7
Market sourced					
LM5 (Mwatate)	80.5a	35.6a	18.1a	35.5b	1.3b
LM4 (Wote)	73.7b	29.4b	9.8b	50.8a	2.4a
LM 5 (Makindu)	67.1b	26.6b	10.4b	54.0a	1.6b
Mean	76.0	32.3	14.5	43.0	1.6
LSD (p< 0.05)	14.0	6.7	14.8	19.4	2.4
CV (%)	21.0	23.8	116.1	51.5	170.2

Means with different letters are significantly different (p< 0.05) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance

The mean percentage of infected seedlings on farm saved and market sourced seeds was at 14.4% and 10.6% respectively. In farm saved seeds the highest percentage of infected seedlings was in seeds from Mwatate which was significantly different with the seeds from the other two areas both at 12.7%. Percentage composition of mouldy and dead seeds was not significantly different across the three agro-ecological zones (Table 3.6).

In market sourced seeds the highest composition of infected seeds was on seeds collected from Mwatate and Wote at 12.4% and 13.3% respectively which was significantly different with the seeds from Makindu. The mouldy seeds composition varied significantly across the three agro-ecological zones with Makindu having the highest (25.3%) followed by Wote and Mwatate at 13.8% and 5.6% respectively whereas there was no significant difference in the dead seed composition across the three agro- ecological zones (Table3.6).

Table 3. 6: Percentage infected, normal and dead seeds in farm saved and market sourced seeds in different agro- ecological zones in Makueni and Taita Taveta

Agro-ecological zones	Infected Seedlings	Mouldy Seeds	Dead Seeds
Farm saved			
LM5 (Mwatate)	19.0a	6.4a	4.4a
LM4 (Wote)	12.7b	11.6a	17.9a
LM 5(Makindu)	12.7b	10.8a	17.8a
Mean	14.4	9.9	13.4
LSD(p< 0.05)	10.3	8.8	14.9
CV (%)	91.7	112.6	143.6
Market sourced			
LM5 (Mwatate)	12.4a	5.6c	6.6a
LM4 (Wote)	13.3a	13.8b	10.3a
LM 5(Makindu)	3.0b	25.3a	6.0a
Mean	10.6	11.7	7.3
LSD(p< 0.05)	9.5	8.0	10.0
CV (%)	102.2	78.3	155.5

Means with different letters are significantly different (p< 0.05) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance

The mean seedling length in farm saved and market sourced seeds was 10.7cm and 9.6cm respectively. Seeds from Mwatate and Makindu were the highest and not significantly while Wote had the least which was not significantly different with the ones from Makindu. The market saved seeds from Mwatate and Wote were the highest and significantly different with the ones from Makindu. The mean dry weight of seedlings in farm saved and market sourced seeds was 13.2g and 12.8g respectively. In the farm saved seeds, dry weight of seedlings from Mwatate and Makindu was the highest and significantly different from the ones from Wote. In market sourced seeds, seedlings from Mwatate and Wote were the highest and significantly different with the seeds from Makindu (Table 3.7).

The mean vigour index of farm saved and market sourced seeds was at 832 and 734 respectively. Vigour index of farm saved seeds from Mwatate was the highest and significantly different with the seeds from the other two areas. This is similar to the market sourced whereby Mwatate also recorded the highest vigour index and Makindu recorded the least (Table 3.7).

Table 3. 7: Vigour of farm saved and market sourced seeds from different agro-ecological zones in Makueni and Taita Taveta

Agro-ecological zones	Seedling length (cm)	Seedling dry weight (g)	Vigour index I
Farm saved			
LM5 (Mwatate)	12.4a	14.5a	1076.3a
LM5 (Makindu)	10.6ab	14.0a	763.0b
LM4 (Wote)	9.5b	12.0b	722.8b
Mean	10.7	13.2	832.0
LSD (p< 0.05)	3.7	2.6	362.5
CV (%)	44.3	21.8	55.5
Market Sourced			
LM5 (Mwatate)	9.9a	13.4a	811.0a
LM5 (Makindu)	7.4b	9.9b	504.6b
LM4 (Wote)	10.4a	14.0a	746.6a
Mean	9.6	12.8	734.0
LSD (p< 0.05)	3.2	2.3	298.6
CV (%)	37.8	20.1	46.5

Means with different letters are significantly different (p< 0.05) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance

3.6 Discussion

3.6.1 Cowpea seed production and postharvest handling practices

Majority of the farmers were using uncertified seeds of farm saved origin with the dominant cropping system being the intercrop with cereals such as sorghum, maize, and pearl millet. The popularity of uncertified seeds of farm source origin in this study is in concurrence with findings by Almekinders and Louwaars, 2002 who reported that in the developing countries 60-100% of farmers obtain their seeds from the informal seed systems which are farm saved, market sourced or exchange between farmers. Additionally, Wekundah (2012) reported that in Africa, approximately 80% of the farmers use seeds from the informal seed system.

Rubyogo *et al.*, (2007) found out that own farm saved seeds contribute the highest proportion of the supply of the seeds in the informal seed system. The preference of uncertified seeds over the certified ones by farmers is because certified seeds are generally expensive and farmers are unwilling to buy them at a cost twice or more that of the grain price (Sperling *et al*., 2004; Rubyogo *et al*., 2007; Kimani *et al*., 2014). Contrastingly, McGuire and Sperling (2016) reported market as the most common source of seeds used by farmers sourcing seeds from the informal seed system though such seeds are initially farm saved seeds sold to the markets by farmers.

A large proportion of the respondents were producing cowpea on small scale under farm size of 0.25ha. Similar findings were earlier reported by Kimiti *et al.*, 2009 that most of the farmers produced legumes on land area under 1.5ha in some parts of Makueni County. This is because cowpea production is still at subsistence level and there is need to improve and minimize the effect of the constraints in its production (Asiwe, 2009). Ya'aishe and Petu-Ibikunle, (2010) also reported similar findings that most cowpea farmers were small scale in Nigeria. Asiwe (2009) also found out that the area under cowpea was between 0.25 and 2.0ha per farmer in a survey among cowpea farmers in South Africa.

Majority of cowpea farmers realized yields of 201-500 kg/ha with an equally high percentage of farmers not realizing any yields. The characteristic low yields of 201-500 kg/ha in this study is in consistent with findings by Kimiti *et al*., (2009) who reported that cowpea farming was characterized by low yields of 30-416 kg/ha which is extremely low as compared to the yield potential of 1200-1800 kg/ha. Karanja *et al*., (2012) ascribed these extremely low yields to inadequate farm input, low soil fertility, infestation by parasitic weeds such as Striga and long dry spells during the season. Furthermore Saidi *et al*., (2010) observed that increase in cowpea harvesting at leaf stage led to a decrease in grain yield and hence could result to less seeds lower than a variety's yield potential.

Cowpea use as a dual-purpose crop for its leaves and seeds in the areas of study with leaves being more popular agrees by findings by (Bubenheim *et al*., 1990; Kabuye and Ngugi, 2001) who reported that cowpea is produced due to its versatility in the use of its leaves and seeds. The production of cowpea for its leafy vegetables has markedly increased in the recent past as farmers nowadays prefer growth of drought tolerant vegetables due to the current weather prevailing conditions in Africa as reported by Saidi *et al*., (2007). However, the intensity of use of leaves over the seeds varies from locality to locality (Asiwe, 2009).

Intercropping as the common production system in which cowpea is grown is consistent with findings by Asiwe (2009) which showed that intercropping along with mixed cropping of cowpeas along cereals was popular in South Africa. This is in effort to avoid crop failure, optimizing of available labour, efficient utilization of environmental resources, suppression of weed growth, decreasing of damage by pests, improvement of forage yield and quality as well as improvement of soil fertility through nitrogen fixing by legumes (Omiti *et al*., 1999; Olufajo and Sigh, 2002, Katsaruware and Manyanhaire 2009; Dahmardenet *et al*., 2010). However there are contrary findings that cumulative crop yields on the intercropping system is currently on decline due to erratic rains (Jaetzold *et al*., 2006).

The dominant cowpea threshing method was physically hitting with stick while sun drying was subsequently the most common drying method. This is consistent to findings by Gomez 2004 and Taruvinga *et al*., 2014 who reported the method of threshing by beating as very popular among cowpea farmers. Methods of drying such as hanging over the fireplace, smoking and solar drying are popular among cowpea farmers (Kimiywe *et al*., 2015). Varied places of storage were used by the farmers and the most commonly used was the racks inside the house followed closely by the use of granary. The storage containers and materials included nylon sacs, gunny bags, plastic containers storage pots and reed woven baskets with the most popular one being the use of nylon bags. This concurs to findings by Kimiywe (2015), who among other post-harvest storage containers cited use of storage pots, sacks, woven baskets. Recent studies in Nigeria showed that the traditionally preferred methods of storage is in polyethylene bags but pests have made them to turn to alternatives such as metal drums and double bags according to Moussa *et al*., 2011. Additionally CRS, 2013 reported use of plastic containers for cowpea storage due to local availability, ability to re- use over the years although they can only store small quantities of seeds.

Use of these multi-layered plastic bags is reported to have resulted to decrease in the use of storage insecticides from 40% to 6%. However, not all bags are suitable for seed storage except hermatic bags since some such as plastic bags prevents air circulation while tightly woven polypropylene do not allow sufficient air circulation even though they are readily available in the market. Therefore, the best storage bags are UV stabilized polypropylene with special weave that allows for air circulation or jute bags (Tavuringa *et al*., 2014). Although these airtight storage techniques are available and suppress damage of cowpea storage pests such as weevils the farmers persist in the use of low quality storage bags (Sanon *et al*., 2011, Ainika *et al*., 2012).

Popular products used for seed treatment was use of the compounds containing Pirimiphos methyl and Malathion 2% + Permethrin 0.3w/w active ingredients, ash and others such as paraffin, oil and smoke respectively. This is in agreement with earlier findings by Apuuli and Villet, 1996 who reported that ash is effective in control of damage of cowpea seeds in storage through restricting the movement of beetles among the seeds, hampering the oviposition and interference of the immature stages of the storage pests through abrasion. Recent findings by Houssou *et al*., 2010 showed that use of ash for cowpea seed storage was among the traditional methods of cowpea conservation. However, protection of storage seed has become harder nowadays due to decreasing active pesticide active ingredient and increasing pesticide resistance (Arthur, 2012).

3.6.2 Effect of seed source on analytical purity

The mean percentage pure seed composition of farm saved and market sourced was at 73.7% and 84.7% and therefore both were below the recommended quality as they did not meet the minimum pure seed composition of 98% as recommended by ISTA. This finding is in agreement with ICARDA (2002), who also found out that some of the samples (5%) collected from wheat farmers did not meet the minimum recommended rate in Ethiopia. Variety purity of farm saved seeds is reported to be compromised due to the storage practices used by the farmers in Ghana (Bortey *et al*., 2011). Additionally no significant difference was reported in analytical purity analysis of farm saved wheat seeds from different regions in Ethiopia (Ensermu *et al*., 1998). The reduced percentage purity of the seed samples below the recommended rate could also be attributed to poor seed production practices such as failure to rogue out other varieties as well as less than optimum harvesting practices, shelling technique and storage conditions (Greven *et al*., 2007).

Insect damaged seeds were the second highest composition with farm saved seeds having a higher percentage that was more than twice that which was market sourced and was above the recommended limit by ISTA (2015). This is in consistent with earlier findings that showed that insect damage remains a major constraint in cowpea production in African and in other areas growing cowpea (Adipala *et al*., 2000; Asante *et al*., 2001; Makoi *et al*., 2010; Egbadzor *et al*., 2013). Biemond *et al*., (2012) also reported that a high level of damage of cowpea seeds by weevil was the major storage pest was evident among farmers who used traditional storage methods such as polyethylene bags which was the popular storage method in the areas of study.

Other variety component percentage was the third highest component with one region having a composition of as high as 4.1% which was more than the minimum recommended rate by ISTA 2015. This is similar to reports by Hasan *et al*., (1995) who found out that wheat farm saved seeds had relatively high levels of other crop seed contamination and therefore low pure seed component. However Michael *et al*., (2010) reported that it is not possible to completely remove all foreign seeds due to the high cost of sorting and selection. However Bishaw *et al*., (2012) reported that farmers do use local selection, treatment, cleaning and storage to maintain the quality status of their farm saved seeds. Additionally, seed storage heavily affects the plant quality (Shaban, 2013).

3.6.3 Effect of seed source on germination and vigour

Farm saved and market sourced seeds from one of the agro-ecological zones achieved the minimum germination percentage of 75% and was significantly different from the other one. Different agro-ecological zones experience different rainfall amount, temperature and humidity (Jaetzold *et al*., 2006). Sales *et al*., 2013 has reported that the conditions in which the mother plant has been grown heavily influences the seed germination. Additionally, Matikiti *et al*., 2012 reported that factors such as poor storage could result to attacks by bruchids and fungi causing the seeds not to germinate. Additionally, Misangu *et al*., 2007 also observed that seeds with higher incidence of damage by bruchids resulted to lower germination compared to disinfested seeds.

Abnormal seedlings and infected seeds are direct indicators of seed heavily infected by seed borne pathogens (Icishahayo *et al*., 2009). The higher percentage of these two aspects in farm saved seeds varying among the different agro-ecological zones are similar to findings by Icashahayo, 2010 who reported that varying levels of pathogens in bean seeds obtained from different agro-ecological zones in Zimbambwe. Farmers tend to retain and recycle seeds for several seasons hence leading to build up of seed pathogen inoculum negatively affect seeds causing rampant cases of abnormalities in seedlings and post emergency mortality in bean seed (Icishahayo *et al*., 2007; Oshone *et al*., 2014).

A comparison of the performance farm saved and market source seeds showed that there was no significant difference in normal and abnormal seedling, mouldy and hard seeds while a significant difference was in infected seedlings with farm saved having the highest level of infection and dead seeds. The germination percentage and germination rate were not significantly difference in the seeds from the two sources. Similarly farm saved and market sourced seeds were not significantly different in germination as reported also by Walker and Tripp, (1997) who reported no significant difference in germination of farm saved cowpea and sorghum in Ghana and Zambia respectively and those obtained from other sources which are informal.

The seedling vigour index that was the dry weight showed that there was a significant difference in the seedling vigour index of seed samples from the three different areas. The seedling vigour index of farm saved seed samples was significantly different from the ones which were market sourced and had a higher seedling vigour index. This in agreement with results by Bishaw *et al*., 2012 who also reported similar findings while working on wheat from different areas in Ethiopia.

CHAPTER FOUR

EFFECT OF QUALITY OF COWPEA SEED ON CROP ESTABLISHMENT, BACTERIAL BLIGHT OCCURRENCE AND YIELD

4.1 Abstract

Most farmers use various cowpea seed sources such as markets or farm saved as well as a small percent of certified seeds whose effect on crop performance is unknown. A study was conducted during the 2016 short rains in Makueni County at two sites namely Kambi Ya Mawe and Kiboko both in KALRO station in LM 4 and LM 5 respectively. Effect of three different seed sources; certified, market sourced and farm saved and three different cowpea varieties; KVU, M66 and K80 were evaluated. Certified seeds recorded a highest seedling emergence and plant stand and the least percentage of rotten seeds. Generally the yields and yield components in LM5 was higher than in LM4 and hence environment influenced these components. There was no significant effect of seed source on seeds per pod and pod length since they are influenced by genetic composition and environmental aspect. The results also showed that dry grain yield and dry matter yield were highest in certified seeds. Therefore for the farmers whose basic interest in the cowpea crop is dry grain yields, certified seeds are recommended as other parameters such as seeds per pod and pod length are basically genetically controlled.

Key words: Cowpea, seed source, seed emergence, yield parameters, Makueni.

4.2 Introduction

Cowpea (*Vigna unguiculata*)is said to be one of the most ancient crop to be known to man and it is grown across varying agro-climatic conditions but most commonly in the dry areas of Sub Saharan Africa as a sole crop or when intercropped with cereals like sorghum or millet (Singh *et al*., 1997; Agbogibi, 2010a). Recent studies suggest that the centre of origin might have been in the Central African Region (Ogunkamni *et al*., 2006).

It is a multipurpose legume hence very attractive to farmers in marginal and drought prone areas receiving low rainfall and also have limitation in terms of irrigation systems hence other legume food crops do not perform well (Singh *et al*., 2003; Hallensleben *et al*., 2009). Previously it had been popular for it nutritious protein-rich grain commonly consumed together with cereals but in the recent times more subsistent farmers have shifted into its production as a more drought tolerant indigenous vegetable as a result of repeated drought occurrence in many part of Africa (Saidi *et al*., 2007; Dugje *et al*., 2009).

Nutritionally, the cowpea crop is commonly referred to as the poor man's meet in West Africa due to the rich nutritional composition of 22% protein, 1.4% fat, 59.1 carbohydrates and 3.7% ash. This rich composition makes it recommendable for consumption by pregnant mothers when cooked alone as mature seeds or together with other vegetables as accompaniments to cereal meals (Vanderborght and Baudoin, 2001). The world's population is increasing and so is demand for more food to feed the increasing population. However achieving this has apparently been a challenge due to ever decreasing arable land safe for the arid and semi arids areas that are used for production of drought tolerant crops such as cowpea. This crop is capable of surviving under the most adverse agricultural conditions anywhere in the world (Owolade *et al*., 2006; Muoneke *et al*., 2012). It is grown by resource-constrained farmers who buy certified seeds once and recycle it for the subsequent seasons. Additionally cowpea certified seeds are not readily accessible at planting time since private seed producers considers production of these seeds less lucrative due to low demand compared to the open pollinated crops especially cereals (Almekinders and Louwaars, 2002; Kimani *et al*., 2014).

Seed of high quality is one of the key factors to ensure successful crop as the establishment of an adequate plant population in the field is necessary to achieve high productivity. Seed physiological quality is commonly assessed via germination test whose results are considered as reliable in terms of reproducibility and seed official inspection. However this does not always demonstrate the same efficiency in estimating seed performance after sowing, since field seedling emergence results are often lower than those observed in laboratory germination (Marcos- Filho, 1999). To a farmer seed is actually the only way to benefit from investments in crop improvement and therefore high quality of seed is essential in establishing a sufficient crop stand that will directly influence crop performance in terms of yields (McGuire, 2005). Therefore, there was a need to evaluate the effect of the cowpea seeds sources used by farmers on the effect of emergence, plant stand, incidence and severity of bacterial blight of cowpea and yield and yield components.

4.3 Materials and methods

4.3.1 Description of the study area

The sites were in Kiboko and Kambi Ya Mawe areas. The areas are classified into agro-ecological zones (Table 4.1).

Table 4. 1: Characteristics of the agro-ecological zones of the experiment sites

Region	AEZ	Altitude (m)	Average temp(˚C)	Annual rainfall(mm)	Description of characteristics	Soil type
Kambi Ya Mawe	LM4	1120mm	22.0˚C-21.3˚C	566mm	Marginal Cotton zone	Ferralsols-orthic acrisols
Kiboko	LM5	975mm	24.0˚C-21.6˚C	601mm	Livestock-millet zone	Cambisols

LM4= Lower midland zone, LM5= Lower midland zone, AEZ=Agro-ecological Zone, Source: Jaetzold *et al*., 2009

4.3.2 Field experiment layout and design

The experiments were carried out in two sites namely Makindu and Wote in Makueni County during the 2016 short rain. A set of samples of 1kg of cowpea varieties KVU, K80 and M66 in the area of study were collected from market places, farmers and certified seeds. They were laid down in a randomized complete block design (RCBD) in Split plot layout. The main plot was the seed source measuring 9m by 3m while the subplots had the three different varieties measuring 3 by 3 meters. The crop spacing was 60cm row to row and 20cm plant to plant with 4 seeds per hill that gave it a plant population of 150 plants per plot.

4.3.3 Assessment of seedling emergence

Field emergence evaluation was conducted as stated by Biemond *et al*., (2012) 14 days after planting the crops was evaluated for emergence which involved counting the number of emerged seedlings as a percentage of the total seeds planted in each plot. This procedure was repeated on each of the plots.

4.3.4 Assessment for plant stand

Plant stand count was evaluated as the total number of cowpea plants in each plot at two weeks. Evaluation was done on the 2^{nd}, 4^{th} and 6^{th} week respectively from the date of planting.

4.3.5 Assessment for bacterial blight incidence and severity

Disease incidence was determined will be in reference to the number of plants showing infection with bacterial blight in 14 days interval from planting to podding in each of the plot divided by total plants per plot times a hundred. Disease severity was determined using be a disease score scale of 1-5.

$$\text{Incidence} = \frac{\text{No.of infected plants}}{\text{Total number of plants per plot}} \times 100$$

Diseases severity scale: 0= No disease, 1= 26-50% of the area is infected, 2= 51-75% of the leaf area is infected, 3= 76-99% of the leaf area infected, 4= Completely dead

4.3.6 Assessment for yield and yield components

Yield and yield components were assessed using modified formula by Egho, 2010. Number of pods per plant was determined by picking all the pods in the middle row of the plot and then counting the number of plants on the same row.

No. of pods per plant= No. of pods/No. of plants

The pod length and seeds per pod was determined by randomly picking 30 pods from the ones harvest in the middle row and measuring determining the length of each pod using a ruler in cm and subsequently determining the number of seeds in each of those pods.

After harvesting the pods were manually shelling and sorting done for each of the plots and subsequently weighing the harvest from each plot to obtain dry grain yield and the weight was extrapolates to kg/ha. A thousand seeds were counted and the weight determined using a digital scale and the procedure repeated on each plot. The dry matter yield was determined by sun drying the stover weighing for every plot and then expressing it to kg/ha.

4.4 Data analysis

The data obtained from seedling emergence, plant stand, diseases incidence and severity and yield parameters was analysed using GENSTAT© statistical package and means separated using Fisher's protected LSD at $P \leq 5\%$.

4.5 Results

4.5.1 Effect of seed source on crop establishment

There was no significant difference in seedling emergence of market sourced and certified cowpea seed which were the highest and significantly different from farm saved seeds which recorded the least emergence in Lower midland sub zone iv (LM4). In Lower midland subzone v (LM5), cowpea seeds of certified and market source had the highest seedling emergence which was significantly different with the farm saved cowpea seed. Overly, mean seedling emergence of seeds sown in LM5 was higher than the ones obtained from LM4 (Figure 4.1).

A significant difference was observed among the three sources and between the sites. In both sites the farm saved seeds had the highest percentage of rotten seeds followed by certified and market seeds respectively. It was also noted that LM4 recorded relatively higher percentage of rotten seedlings in farm saved and certified seeds which was significantly difference with the ones of market origin which were not significantly different (Figure 4.2).

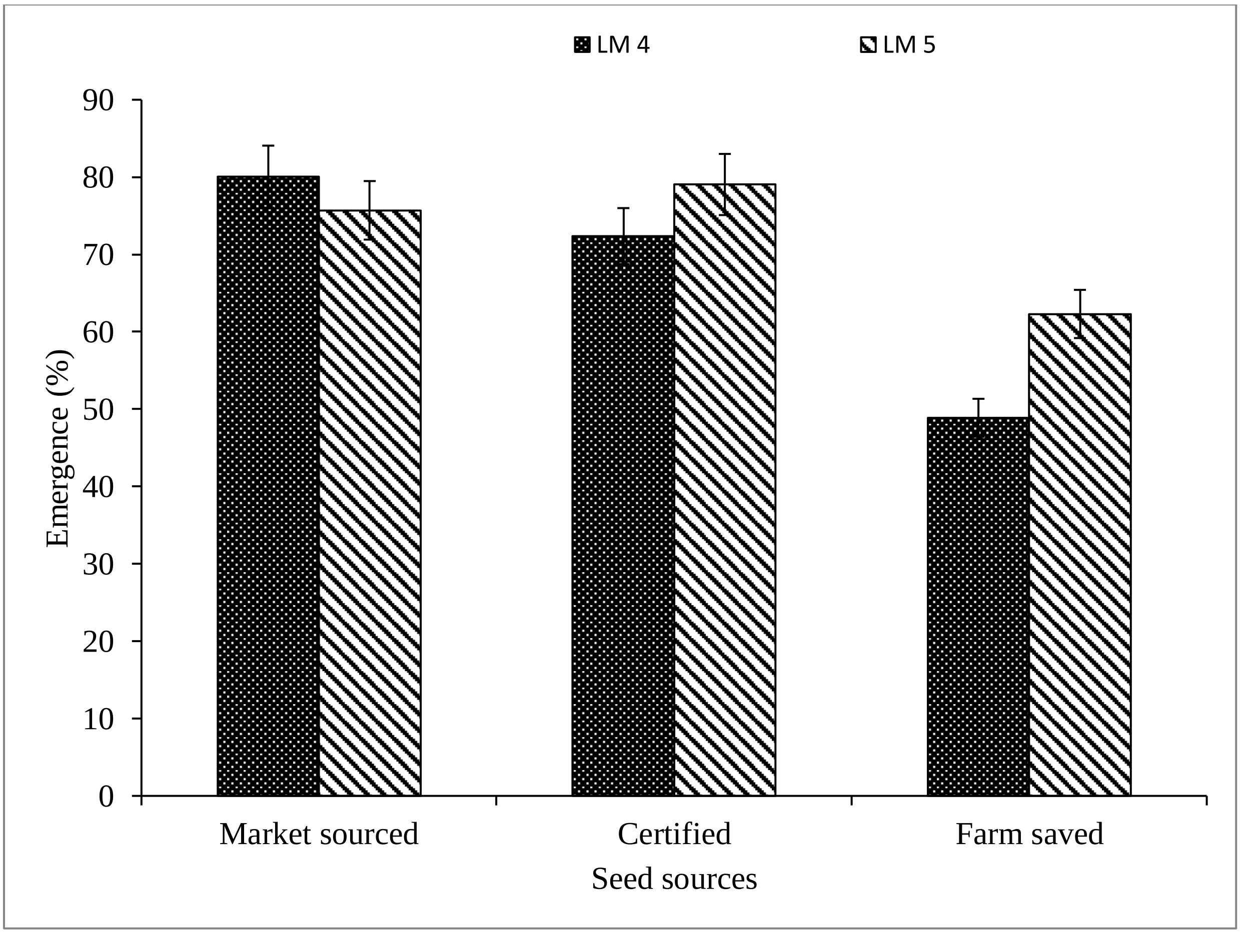

Figure 4. 1: Percentage emergence of cowpea seed from different sites in site in two different agro- ecological zones

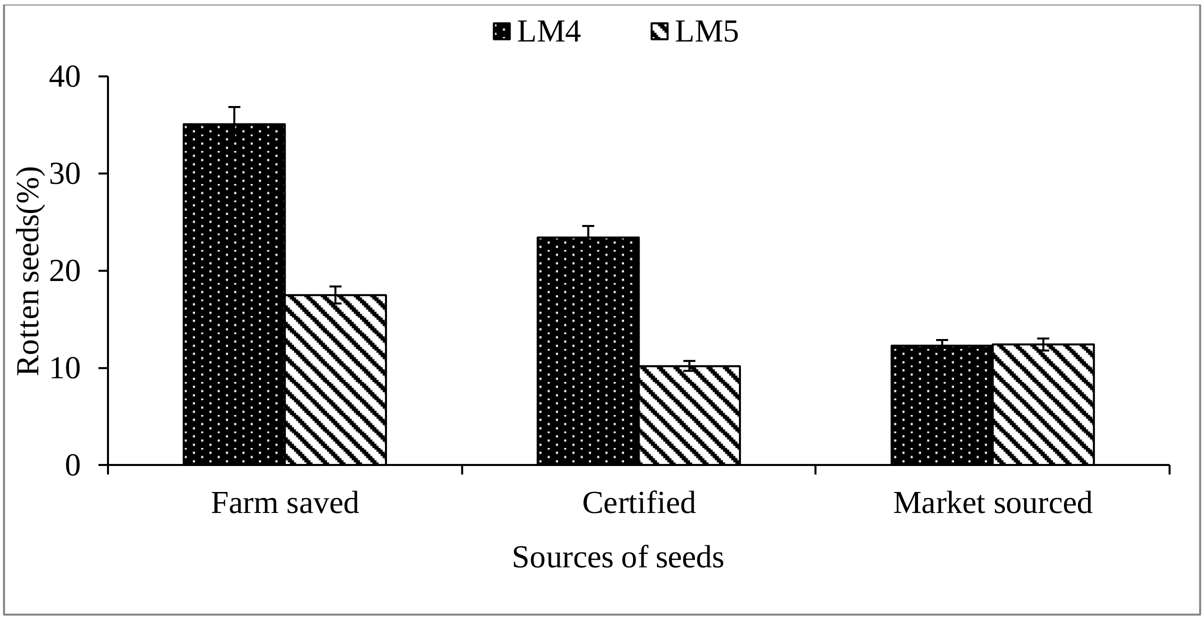

Figure 4. 2: Percent rotten seeds in cowpea seed from different sources in two sites

Table 4. 2: Plant stand count of cowpea seed from different sources in two sites at 2nd, 4th and 6th week after emergence

Seed Source	Kambi Mawe	Kiboko
2nd Week after emergence		
Market sourced	96.6a	110.2a
Certified	98.8a	107.1a
Farm saved	61.1b	91.7a
Mean	85.0	103.0
LSD (p< 0.05)	23.1	20.6
CV (%)	27.2	20.2
4th Week after emergence		
Market sourced	96.6a	110.2a
Certified	98.8a	107.1a
Farm saved	61.1b	91.7a
Mean	85.0	103.0
LSD (p< 0.05)	23.1	20.6
CV (%)	27.2	20.2
6th Week after emergence		
Market sourced	96.6a	106.4a
Certified	98.8a	105.8a
Farm saved	61.1b	87.6a
Mean	85.0	99.9
LSD (p< 0.05)	23.1	23.3
CV (%)	27.2	23.5

Means with different letters are significantly different (p< 0.05) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance

There was a significant variation in plant stand between the sites and among the seed sources. In general, the site in LM5 had a higher plant stand compared to the one in LM4. In LM5, plant stand was not significantly different in the three sources and there was no variation across the two weeks interval. In LM4, plant stand was highest in in market sourced and certified seed sources which was significantly different with farm saved. However no variation in plant stand across the 2 weeks interval in LM4 was recorded (Table 4.2).

4.5.2 Effect of cowpea seed source on incidence and severity of bacterial blight of cowpea

There was a significant variation in incidence of bacterial blight of cowpea between the sites and among the seed sources. At 14 days after planting, in both sites incidence in certified and farm saved was highest and significantly different from the ones recorded in market sourced. At LM4 site the incidence level was higher than in the other site. At 28 days after planting, in LM4 site there was no variation in incidence from one recorded at 4weeks after planting whereas in LM5, farm saved and certified recorded the highest incidence level (Table 4.2).

Table 4. 3: Bacterial blight of cowpea disease incidence and severity in cowpea seed from different sources in two different sites

Seed Source	Kambi Mawe		Kiboko	
	Incidence	Severity	Incidence	Severity
2nd Week				
Certified	30.6a	0.9a	22.7a	0.5a
Farm saved	31.8a	1.0a	18.7a	0.5a
Market sourced	19.2b	0.8a	11.4b	0.4a
Mean	27.2	0.9	17.6	0.4
LSD	11.1	0.2	5.8	0.1
CV(%)	41.3	22.8	33.3	32.2
4th Week				
Farm saved	31.8a	1.7a	25.5a	0.7b
Certified	30.5a	1.7a	19.6ab	0.8ab
Market sourced	19.2a	1.6a	17.6b	0.9a
Mean	27.2	1.7	20.6	0.8
LSD	11.1	0.1	6.7	0.1
CV(%)	41.3	7.5	33.1	18.6

Means with different letters are significantly different ($p < 0.05$) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance, AEZ= Agro-ecological Zone

There was no significant variation in bacterial blight severity level between the two sites. At 2weeks after planting in both sites there was no significant difference among the seed sources whereas at 4weeks after planting, in LM5, market sourced and certified seeds recorded the highest level of disease severity which was significantly different with the level from farm saved seeds (Table 4.3).

4.5.3 Effect of seed source on the yield and yield components of seeds used by farmers

All the yields and yields components from the two sites varied significantly whereby the performance of the cowpea crop at agro-ecological zone LM5 was higher than the ones from agro-ecological zone LM4. In both sites, the three seed sources had no significant difference in seeds per pod and pod length component parameters. In agro-ecological zone LM4, the three sources did not have a significant effect on pods per plant (Table 4.4).

In agro-ecological zone LM5, farm saved seeds had the highest pods per plant which was significantly different from the other sources. There was no significant difference of seed source on a 1000 seed weight in agro-ecological zone LM4 whereas in agro-ecological zone LM5, market sourced seeds had the highest a 1000 seed weight which was significantly different with the ones from the other two sources (Table 4.4).

The dry grain yield weight in agro-ecological zone LM4 was not significantly affected by the seed source whereas in agro-ecological zone LM5 it was affected since certified seed source recorded the highest yield which was significantly different with the one from the other two sources. The dry matter yield varied significantly across the two sites whereby at agro-ecological zone LM5 seed source had no significant difference on the dry matter yield weight. In agro-ecological zone LM4, dry matter yield weight from certified seed was the highest and significantly different from the ones from the other two sources (Table 4.4).

Table 4. 4: Yield and yield components of cowpea seed from different sources in two different sites

Cowpea seed source	Pods per plant	Seeds per pod	Pod length	1000 seed weight	Dry grain yield	Dry matter yield
LM 4						
Farm saved	6.9a	7.9a	11.8a	129.7a	262.0a	1722.0b
Certified	5.7a	7.6a	11.8a	116.3a	285.0a	2443.0a
Market sourced	4.6a	8.0a	12.0a	134.2a	289.0a	1831.0b
Mean	5.7	7.8	11.8	126.7	279.0	1999.0
LSD (p≤0.05)	2.3	1.6	1.1	16.8	62.0	480.3
CV (%)	40.5	20.8	9.1	13.4	22.5	24.3
LM 5						
Farm saved	17.4a	12.0a	16.6a	126.8b	1474.0ab	6367.0a
Certified	14.3ab	12.5a	16.8a	130.5b	1743.0a	6704.0a
Market sourced	11.8b	12.7a	16.9a	135.6a	1343.0b	5719.0a
Mean	14.5	12.4	16.8	131.0	1520.0	6263.3
LSD (p≤0.05)	6.5	3.4	0.7	4.5	274.9	2061.7
CV (%)	26.2	15.9	8.9	3.5	18.3	33.2

Means with different letters are significantly different ($p < 0.05$) with the Fisher's multiple range tests, LSD= Least Significant Difference, CV= Coefficient of Variance

4.6 Discussion

4.6.1 Effect of seed source on cowpea crop establishment

There was a significant variation in mean seedling emergence between the two sites with the agro-ecological zone LM5 site recording a generally higher mean seedling emergence. Difference in soil moisture content and the fluctuation of rain during emergence stage as well as soil borne pathogen inoculum suppress seed emergence especially on the early stages of growth (Butt *et al.*, 2011; Dube *et al.*, 2014). Additionally, Koger *et al.*, 2004 reported that environmental factors such as temperature, soil moisture, pH and light significantly affect seed germination and this could explain the difference in seedling emergence between the two sites.

The result showed significant effect of seed sources on seedling emergence that was consistent across the sites with certified and market sourced seeds having a considerably higher emergence than farm saved. This findings concurred with Asiedu *et al.*,(2007) who observed that seeds from certified sources had a lower seedling count and plant count reduction towards harvesting of 9% and 12% respectively compared to 21% and 23% respectively observed in farm sourced seeds he was however working on maize. However, Biemond *et al.,* (2013) researching on the levels of contamination of farm saved and certified seeds with seed borne diseases found out that the level of infection was higher in certified seeds was higher than in farm saved seeds.

Percentage of rotten seeds was highest in farm saved seeds and was significantly difference with the ones from the other two sources. Icishahayo, 2009 reported that rotten seeds are directly related to the level of pathogen inoculum in the soil. Additionally, Amaza *et al*., 2010 reported that farm saved seeds are characterised with recycling for several season which negatively affect the seed quality. These seeds are also subjected to damage by storage pests and accumulation of seed pathogens which affect the crop performance adversely (Matikiti *et al*., 2012; Kimiywe, 2015). Agro-ecological zone LM4 site recorded a significantly higher level of rotten seeds compared to agro-ecological zone LM5 site. This concurs with findings by Icishahayo, 2010 who reported a difference in pathogen incidence in bean seeds obtained from different agro ecological zones in Zimbambwe. Contrastingly, there were high frequencies of seed borne pathogens in seeds collected from highland areas than those from lowland areas (Mohammed and Somsiri, 2005; Makelo, 2010 ; Mutisya *et al*., 2013).

Certified and market sourced seeds recorded a significantly higher plant stand than the farm saved seeds. This is in agreement with Asiedu *et al*., (2007), who reported that certified seeds had a lower plant stand count reduction of 12% compared to farm saved seeds which had a reduction of 23% while working on maize. The difference in performance of the crop across the two sites could be attributed to difference in the level of infection by soil borne pathogens which results to reduced seedling germination and subsequent post emergence damping off hence a reduction in plant stand count (Marisol *et al*., 2008; Botelho *et al*., 2013).

4.6.2 Effect of seed source on incidence and severity of bacterial blight

A significant difference in incidence of bacterial blight of cowpea was recorded between the sites. Ajeigbe *et al*., 2008 also reported that there was a difference in incidence of bacterial blight among sites which had high negative correlation with grain yields in sites most severely affected. Nandini, 2012 also reported a variation in cowpea bacterial blight incidence among different district in India it is dependent on various factors like relative humidity, rainfall, and temperature. The higher disease incidence in agro-ecological zone LM4 may be attributed to the generally heavy rain and higher temperature as reported by Jaetzold *et al.,* 2006 which create conducive environment for bacterial blight. Disease severity was almost negligible in agro-ecological zone LM5 whereas in agro-ecological zone LM4 it was at 1-25% percent disease index and not significantly different among the seed sources. This is in contrast with earlier findings by Kotchoni *et al., 2007* who reported that treated seeds showed a lower disease severity compared to untreated seeds.

4.6.3 Effect of seed source on yield

Seed source had no significant effect on seeds per pod, pod length. This is consistent to findings by Idahosa *et al*., (2010) and Agbogidi (2012) who also found similar variations on their studies on genetic variation, heritability and advances on yields of cowpea which included seeds per pod and pod length. Earlier work also showed that pod length is genetically controlled and hence minimally influenced by environmental factors. It was concluded that the response of plant to environmental factors is determined by their genetic composition and also on degree of adaptation (Siddique and Gupta, 1991; Tyagi *et al*., 2000). These finding are however in contrast to classification of cowpea yield components by (Aliyu and Makinde, 2016) who classified these two as environmentally none sensitive.

In agro-ecological zone LM5, certified seeds source recorded the highest dry grain yield which was significantly different with the one from the other two sources. This findings were similar to the work by Asiedu *et al*., 2007 working on certified and farm saved seeds found out that the certified seeds were superior to farm saved seeds especially on the grain yield. Additionally, Sofijanova *et al.,* 2012 reported that average yield in wheat; a self-pollinated crop from certified seed source was 22.5% higher than those from uncertified sources. Use of good quality seed generally can result to increase in yield by 20-30% (Mula, 2012). Farmer saved seeds is generally of unknown quality and hence their use risk low emergence and plant vigour and eventually resulting to poor physiological quality (Matthews *et al*., 2012). Additionally use of seeds of low quality leads to low germination, seedling mortality, stunted growth and eventually low yields (Solorzano and Malvick, 2011).

The certified seeds are treated with fungicides and hence the significant difference in grain yield compared to the performance of seeds of untreated source since the treatments exert control over pests and pathogens (Consuelo *et al*., 2000; Akoth *et al*., 2010). Lilian *et al*., 2012 also revealed that the positive effect of treated seed on grain yield could be attributed to the better emergence and plant stand count which resulted to increased yields. Furthermore, Maphosa *et al.,* 2016 working on legume seeds from different seed sources revealed that certified seeds had the least disease infection level and therefore could be forecasted to achieve highest grain yield. These results were contrasting to findings by Biemond *et al.,* 2013 who found out that the certified cowpea seed were more heavily infected with seedborne pathogen than farm saved seeds which have major effects on the dry grain yield. Dry matter yield from certified seed source was the highest and significantly different from the ones from the other seed sources. Sofijanova *et al*., 2012 revealed that certified wheat seed use did not only lead to use of less seed per unit area but also ensured more income and straw compared to use of certified seed source.

In conclusion this study showed that the seeds source cannot solely affect all the components of yield since some are environment sensitive particularly seeds per pod and pod length since they are also genetically controlled. Dry grain yield is one of the most important cowpea yield component to the farmer and is evidently affected by the seed source as the certified seeds recorded the highest dry grain yields. These higher yields are related to the fact that the seeds are usually seed dressed and hence suppresses pests, soil borne and seed borne pathogens hence a high crop stand which positively affect yield component. Therefore seed source have effect on crop performance especially dry grain yield and dry matter yield which are of economic importance to most farmers and hence to achieve optimally farmers ought to use certified cowpea seed.

CHAPTER 5: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

The farmers in the three areas of studies majorly use seeds from the informal seed system which are mainly of farm saved origin while few of them use seeds from the markets due to their availability and affordability during the planting season (Rubyogo *et al*., 2007, Wekundah, 2012). The popular cropping system in cowpea production is intercrop with cereals such as sorghum, pearl millet and maize (Asiwe, 2009) as it has various benefits as reported by (Omiti *et al*., 1999; Olufajo and Sigh, 2002, Katsaruware and Manyanhaire 2009; Dahmardenet *et al*., 2010). Majority of the farmers are small scale growing cowpea on less than 4ha of land with characteristically low yields below the potential yields (Asiwe, 2009; Kimiti *et al.*, 2009). The dominant threshing and methods of drying are physically hitting and sun drying (Gomez, 2004; Taruvinga *et al*., 2014) while common storage places are in the house racks and granary in polyethylene bags and plastic containers (Kimiywe, 2015).

The seeds did not meet the minimum pure seed composition of 98% or the minimum insect damaged seed composition of 1.4% whereas only farm saved seeds from Taita met the minimum recommended germination percentage of 75% (ISTA, 2015). The seedling vigour of the seeds from the different areas and seed sources were significantly different (Bishaw *et al*., 2012). Therefore generally these seeds farm saved and market sourced seeds are of low quality and not recommendable for crop production.

The seed source influenced seedling emergence, rotten seeds and plant stand. Certified seeds had the highest seedling emergence and plant stand whereas farm saved seeds had the highest percentage of rotten seeds. The incidence and severity of bacterial blight of cowpea was not influenced by the sources by the environment since they were both higher in one of the agro-ecological zones. Seed source did not influence seeds per pod and pod length since they are both basically influenced by the genetic composition and environment. Dry grain yield and dry matter yield was influenced by seed source since they were both highest in certified seeds. However dry grain yield which is the component of interest to farmers was found to be higher in certified seeds than in the other seed sources (Grema ,1995; IITA, 1998; Futuless and Bake, 2010).

5.2 Conclusions

Use of uncertified cowpea seed by farmers is a common practice among the cowpea producing farmers who are majorly located in the ASALs areas of Kenya. Recycling of these seeds over several seasons over the years is also a common practice which leads to low seed quality and subsequently low yields as revealed in this study. Cowpea is identified as an essential crop in the cropping system of these areas due to its unique characteristics such as drought tolerance, ability to grow on soils of low fertility and subsequent nitrogen fixation, multipurpose use and early maturing nature hence need for constant supply of quality seeds to ensure worthwhile harvests. The farmers are currently faced with the challenge of seed storage methods as majority of them use polyethylene bags which are unsuitable due to the susceptibility of the seeds to storage insects which cause seed damage. These results to low pure seed component and loss of seed viability especially where the seed embryo is damaged.

The seeds from the areas of study did not meet minimum recommended standard with reference to pure seed composition due to poor storage resulting to high component of insect damaged seed composition. Only seed samples from Taita attained the minimum recommended germination percentage and its notes worthy that the majority of respondents from this area were using certified seeds. Therefore it is evident that replenishing of own saved seeds with certified seed once after several seasons guarantee maintenance of good seed quality. In the determination of yield and yield components on seeds from different sources revealed that the certified seeds did not perform exceptionally superiorly to farm saved and market sourced seeds as it would be easily assumed. This is probably due to lack of stringent measures during certified seed production inspection and hence the need to ensure more keenness during seed production inspections.

Cowpea seed from the informal seed system cannot be dismissed off as of low quality as they performed equally well in terms of germination percentage, seed vigour and yield and yield components. Therefore, efforts should be put in place in order to train farmers on production, seed storage and treatment so as to ensure that high cowpea seed quality is maintained in the informal seed system whose role is key in the agricultural food production and subsequently high income, improved livelihood and eventually food security despite of the ever changing climate.

5.3 Recommendations

From the conclusion, it is recommended that;

i. Farmers should be trained on proper cowpea crop production practices such as management of cowpea pest at pre- and post -harvesting period.
ii. Training of farmers and market seed sellers on proper post- harvest cowpea seed, handling practices such as proper drying, sorting, seed treatment and occasional checks for seed quality during storage.
iii. Studies on cowpea seed health be conducted as seed health is vital in cowpea productivity
iv. Awareness on the importance of seed quality to should be made and emphasized to the farmers and importance of replenishing their seeds with certified seeds more often.

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APPENDICES

Survey questionnaire for determination of quality of cowpeas used by farmers.

1) Name of the farmer……………………………………………………………………….
   a) Sub county………………………
   b) Location………………………………… Sub location…………………….
   c) Village……………………………………… Agro ecological zone…………..
2) What is the size of your farm? ....
3) What is the size of area under cowpea?
   a) 0.5 acre
   b) 1 acre
   c) More than 1 acre
4) Which varieties of cowpea do you produce?

5a) Do you produce cowpea in mixed crops? Yes …….No…..

b) If yes what do you intercrop it with?

a) Maize
b) Sorghum
c) Millet
d) Cassava

6a) Which types of seeds do you use?

a) Certified…………………………..
b) Uncertified………………………..

b) If uncertified, do you use

a) Farm saved……………………………….

b) Market seed………………………………

c) From other farmers……………………….

d) Others………………

i) Do you do any seed treatment before planting?

ii) What do you consider while sourcing for your seeds?

7) Have you ever used certified seeds? YES……..NO………..

a) If YES where did you obtain the certified seeds from?

A. Research institution

B. Seed company

C. Agrovet shop

b) Did you see a difference in performance? YES …….NO……

c) If YES, which ones? ....

d) How much was the yields……………………

8) What are the reasons for not using certified seeds always?

a) Cost………………………………………..

b) Availability…………………………………..

c) Market preference……………………………….

Others……………

9) For how many times have you reused the certified seeds?

10) Which challenges do you face in cowpea production?

If pest and diseases, please indicate;

Pest	**Control**
